Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

DRAFT REPORT
GEOTECHNICAL AND HYDROLOGICAL INVESTIGATIONS FOR THE MIDWAY AND KENT HIGHLANDS LANDFILL CLOSURES

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PREFACE

In accordance with contract G-81-22 between the City of Seattle and Parametrix, Inc. dated December 2, 1981, Golder Associates, under subcontract to Parametrix, Inc., has conducted geologic and hydrologic studies to determine subsurface conditions and provide geotechnical and hydrological design criteria for the closure of the Midway and Kent Highlands landfills. This report, which summarizes our findings and recommendations, is divided into two parts:

Part I - Midway landfill
Part II - Kent Highlands landfill

PART I

MIDWAY LANDFILL

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
1.1	GENERAL SITE DESCRIPTION	2
1.2	PURPOSE AND SCOPE	
2.0	INVESTIGATION PROGRAM	4
2.1	REVIEW OF EXISTING DATA	4
2.2	FIELD INVESTIGATIONS	4
2.2.1	Drilling	4
2.2.2	Groundwater Sampling Well Installation	5
2.2.3	Groundwater Sampling and Testing	7
2.2.4	Methane Gas Sampling Well Installation and Monitoring	8
2.2.5	Surface Water Mapping	9
2.2.6	Surveying	9
2.3	COVER MATERIAL SEARCH	9
2.4	LABORATORY INVESTIGATION	9
2.4.1	Gradation	10
2.4.2	Compaction	10
2.4.3	Moisture Content	11
2.4.4	Permeability	11
3.0	GEOLOGIC AND HYDROLOGIC CONDITIONS	12
3.1	GEOLOGY	12
3.1.1	Regional	12
3.1.2	Site Specific	12
3.2	SURFACE WATER	14
3.2.1	Regional	14
3.2.2	Site Specific	14

TABLE OF CONTENTS (Cont.)

		Page
	3.3 GROUNDWATER	15
	3.3.1 Regional	15
	3.3.2 Site Specific	16
	3.4 METHANE GAS	18
4.0	ELEMENTS OF A CONCEPTUAL CLOSURE DESIGN	19
	4.1 REGULATORY REQUIREMENTS	19
	4.2 SURFACE WATER MANAGEMENT	22
	4.3 LEACHATE/GROUNDWATER MANAGEMENT	23
	4.3.1 Soil Cover	24
	4.3.1.1 Leachate Production	24
	4.3.2 Leachate Collection	25
	4.3.3 Groundwater Collection	26
	4.4 METHANE GAS MANAGEMENT	28
	4.5 FINAL GRADE CONTOURS	30
	4.6 FINAL COVER DESIGN	31
5.0	MONITORING PROGRAM	36
	5.1 SURFACE WATER	36
	5.2 GROUNDWATER	36
	5.2.1 Regulatory Requirements	36
	5.2.2 Monitor Well Locations	40
	5.2.3 Monitor Well Construction	41
	5.2.4 Water Sampling and Analysis	42
	5.3 METHANE GAS	43
	5.4 SETTLEMENT	44
6.0	CONCLUSIONS AND RECOMMENDATIONS	46

TABLE OF CONTENTS (Cont.)

	Page
REFERENCES	48
APPENDIX A - DOCUMENTS OBTAINED FOR REVIEW	
APPENDIX B - GEOTECHNICAL LOGS	
APPENDIX C - FIELD DATA	
APPENDIX D - COVER MATERIAL SEARCH	
APPENDIX E - HYDROLOGIC ANALYSIS	
APPENDIX F - INTERIM GAS INTERCEPTOR TRENCH - MIDWAY	

LIST OF TABLES

Table

4-1 Permeability and Compaction Test Results

5-1 Maximum Contaminant Levels Under EPA Solid Waste Classification Criteria

5-2 Primary and Secondary Drinking Water Standards

5-3 Recommended Groundwater Analysis

LIST OF FIGURES

Figure	
1-1	Location Plan - Midway Landfill
2-1	Borehole and Methane Gas Sampling Well Location Plan
3-1	Midway Landfill - Cross Sections A-A', B-B', C-C'
3-2	Grain Size Distribution Bulk Samples
3-3	Ground Surface Contours - Midway Landfill
3-4	Approximate Location of Existing Drain Lines and Surface Water Ponds
3-5	Approximate Regional Water Level Contours
3-6	Groundwater Elevations
3-7	Water Elevations in Surface Ponds and Wells, Completed within the Landfill Materials
3-8	Conductivity Survey - Groundwater and Surface Water
3-9	Areas of High Methane Gas Concentration
4-1	Schematic of Post Closure Hydrologic System
4-2	Leachate Collection System
4-3	Schematic of System for Groundwater Interception
4-4	Methane Gas Collection System
4-5	Location of Cover Material Samples
4-6	Grain Size Distribution - Cover Material
4-7	Laboratory Compaction Test Results - Cover Material
4-8	Grain Size Distribution - Cover Material
4-9	Laboratory Compaction Test Results - Cover Material
5-1	Proposed Groundwater Monitor Well Locations
5-2	Groundwater Monitor Well Installation
5-3	Proposed Methane Gas Monitor Well Locations
5-4	Methane Gas Monitor Well Installation

1.0 INTRODUCTION

1.1 GENERAL SITE DESCRIPTION

The City of Seattle is currently operating a municipal landfill known as the Midway landfill. The landfill which has been in operation since 1966, is located in Kent, Washington approximately 16 miles south of Seattle (See Figure 1-1). The site is bordered on the east by Interstate 5 and on the west by Highway 99.

The existing landfill is approximately 60 acres in area and up to 120 feet in depth. Review of information concerning the vicinity prior to operation of the landfill indicates that the landfill was placed partially over an abandoned gravel pit and partially over an old peat bog referred to as Lake Mead.

Filling operations on the northern half of the landfill have ceased and there is limited vegetation growing on the top as well as on the side slopes. Surface runoff has caused considerable erosion to some of the existing side slopes exposing the refuse. Filling is currently taking place along most of the south face where material is dumped from haul trucks and spread with dozers. During or at the end of each day the current day's waste is covered with soil that has been hauled to the site or obtained from on-site borrow areas.

Previous to and during the course of operation various drain lines had been placed underneath, in and adjacent to the landfill. The landfill is currently acting as a drain field for surface water collected east of I-5 which is conducted into the landfill through two lines running under I-5. Due to inadequate surface water drainage at the Midway site various surface water ponds have formed, particularly along the northern and western perimeter.

Methane gas is currently being vented and burned at various collector wells in the northern half of the landfill.

1.2 PURPOSE AND SCOPE

Prior to this study no site specific information existed concerning the geologic and hydrologic conditions at the Midway landfill, and thus no conceptual designs for a closure system had been identified. The purpose of this study was to obtain site specific information and ascertain the feasibility of possible closure system elements. Specific objectives were to:

1. Determine the geologic and hydrologic conditions beneath and adjacent to the landfill.

2. Analyze the geological and hydrological conditions in order to determine the technical feasibility of various closure system elements.

3. Address the following elements for a closure system design:
   - o surface water management
   - o leachate/groundwater management
   - o methane gas management
   - o cover design.

4. Provide conceptual geotechnical design details for the proposed elements.

5. Recommend a long term performance monitoring system.

This investigation included a review of existing data, field and laboratory investigations of the site and of potential borrow materials, and an engineering analysis of the collected data to provide designs of various elements of a conceptual closure system.

This study only addresses the geotechnical and hydrological aspects of a closure system. Detailed studies which would be required to assess the current extent of contamination associated with the landfill and a prediction of future contaminant migration are beyond the scope of this study, as is the design of measures to mitigate existing contamination beyond the limits of the landfill.

2.0 INVESTIGATION PROGRAM

2.1 REVIEW OF EXISTING DATA

A comprehensive review of existing information pertaining to the Midway site was undertaken. Included was a review of geologic and topographic maps, aerial photographs of the site taken before filling, water well logs for wells drilled in the vicinity of the Midway landfill, and a report concerning operation of the gravel pit prior to the landfill. Essentially no information was found concerning detailed geologic and hydrologic conditions below or directly adjacent to the landfill. A complete list of all documents concerning the Midway landfill which were reviewed is contained in Appendix A. Pertinent data from these documents are discussed later in this report.

2.2 FIELD INVESTIGATIONS

A field investigation program was undertaken to determine the geologic and hydrologic conditions in, underneath, and directly adjacent to the landfill. The occurrence of surface water and methane gas migration in the vicinity of the site was also assessed. These items are discussed individually below.

2.2.1 Drilling

A series of 11 boreholes were drilled between the dates of January 15, 1982 and February 15, 1982. The location of each borehole is shown in Figure 2-1 and detailed borehole logs are presented in Appendix B.

Four boreholes in the landfill were drilled with a Mobile B-61 drill rig using a hollow stem auger. Two boreholes were completed in the landfill materials (BH-4 and BH-5) and two were advanced through the landfill material into the underlying natural soil (BH-3 and BH-7). Below the landfill samples were collected at 5 foot intervals.

Auger drilling was attempted at three locations outside of the landfill but was unsuccessful due to the auger encountering numerous cobbles and boulders in the subsurface materials. Subsequently, air rotary drilling with the Mobile B-61 rig was attempted. This was successful in BH-2A until a layer of clean gravels was intersected which would not remain stable. These collapsing materials plugged up the hole and jammed the bit. In order to stabilize these collapsing materials drilling mud was used. Mud rotary drilling was used to complete two holes (BH-1B and BH-2A) on the west side of the landfill using biodegradable muds over the intervals which were completed for water sampling to avoid formation plugging.

The remaining two boreholes, BH-8 on the west side and BH-6 on the south side, were drilled with a Speed Star "drill and drive" water well rig. This technique involved air rotary drilling while driving steel casing directly behind the bit using a pneumatic hammer. During all rotary drilling, samples of drill cuttings were collected at 5 foot intervals.

All drilling was conducted under the supervision of a Golder engineer who was responsible for logging the holes and obtaining samples. All samples were returned to the laboratory for classification and index testing.

2.2.2 Groundwater Sampling Well Installation

Groundwater sampling wells were installed in seven boreholes, two within the landfill materials (BH-4 and BH-5), two directly below

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the landfill (BH-3 and BH-7), and three outside of the landfill (BH-1B, BH-6, and BH-8). The wells placed in and below the landfill were constructed of 2 inch threaded Schedule 80 PVC pipe with a 2 foot slotted PVC screen attached to the bottom. The PVC was placed inside the hollow stem auger at the bottom of the borehole. Pea gravel was placed around the screen and the wells were sealed within a specific interval in the borehole using a cement-bentonite slurry.

Two groundwater sampling wells (BH-6 on the south and BH-8 on the west sides of the landfill), placed in boreholes drilled with the Speed Star drill and drive rig, consisted of 4 inch diameter threaded Schedule 40 PVC pipe with the bottom 10 feet slotted. The casing was lowered inside the 6 inch diameter steel casing. Sand and gravel were placed around the slotted section and a bentonite seal was placed on top of the sand and gravel. Subsequently the steel casing was pulled up until it was above the water table. A steel well cover with locking cap was placed over the top of the protruding steel casing.

A special technique was used for completion of the groundwater sampling well installed in the mud-rotary drilled borehole BH-1B. The hole was drilled to a specified depth using bentonite mud to stabilize the hole. A 4-inch threaded Schedule 40 PVC pipe was then placed in the hole and cement was forced into the annulus between the pipe and the borehole. This isolated the bentonite mud from the sample section directly below this level. After the cement had hardened, the borehole was drilled approximately 15 feet further using a biodegradable mud. A 2 inch threaded Schedule 80 PVC pipe and slotted screen were then inserted inside the 4 inch pipe and pushed into the sample interval. A rubber bushing was used to seal the 2 inch pipe against the 4 inch pipe. The biodegradable mud was then broken down and flushed out.

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No PVC cement or solvent was used in the well installation to avoid potential contamination of water samples by organic compounds present in the solvent and cement.

2.2.3 Groundwater Sampling and Testing

On February 22, 1982 all groundwater sampling wells were developed by evacuating water using compressed air for a minimum of a half hour. Wells BH-3, 4, 5 and 7 produced only a fine stream of water after initially expelling the standing water in the well. Boreholes BH-6 and 8 were developed by the same technique but were never blown dry due to the large inflow of water into them. Production rates of 12 and 8 gpm were measured at the completion of drilling in BH-6 and 8, respectively.

During development of all wells except BH-3, water quality samples were taken and analyzed for basic field water quality parameters including temperature, salinity, conductivity and pH, some of which are leachate indicators. Field water quality samples from BH-3 and the Linda Heights well (located east of I-5 in the Linda Heights park) were taken with a nitrogen lift sampler and analyzed. Basic field water quality tests were also conducted in surface water ponds that existed at the time of the field study.

The results of all field water quality tests performed are listed in Appendix C. No laboratory water quality analyses have been completed to date.

Permeability tests were conducted on February 23, 1982 in wells BH-3 and 7 utilizing a bailer to remove water and then monitoring recovery within the sample well. Tests were attempted in BH-6 and 8 but recovery was essentially instantaneous, thus precluding analysis for permeability. The results of the permeability tests are presented in Section 3.3.2.

Water levels in all sampling wells, piezometers and the Linda Heights well were monitored between the dates of January 21, 1981 and April 7, 1982. A summary of water level measurements is presented in Appendix C.

2.2.4 Methane Gas Sampling Well Installation and Monitoring

The Seattle-King County Health Department has placed a series of 19 shallow gas sampling wells west of the landfill. Wells are generally about 42 inches deep, consist of slotted plastic pipe surrounded by gravel and are covered with a slotted PVC cap. The location of these wells are shown on Figure 2-1. In addition to these wells, Golder Associates placed 3 deep gas sampling wells in boreholes BH-1 and BH-2A. These wells consist of 2 inch Schedule 80 PVC pipe with a 2 foot slotted PVC screen attached to the bottom. Gravel was placed around the slotted screen which was sealed within a specific interval in the borehole using bentonite. Methane gas levels were measured by the Health Department on December 15 and 22, 1981 and January 7, 1982 and by Golder Associates on January 12 and February 23, 1982.

Golder Associates also received from the City of Seattle Engineering Department a letter from the Department of Health which contained the results of monitoring for methane gas around the Midway landfill in building structures air spaces (interior-crawl spaces, etc.) in storm drains, and in Pacific Northwest Bell ground vaults. Results of all methane gas monitoring are presented in Appendix C.

2.2.5 Surface Water Mapping

Surface water occurrence was mapped on February 23, 1982. The location of seep areas on the sides of the landfill were also identified. Large areas of ponded water in the proximity of the toe of the landfill were sketched on topographic maps and the levels of these ponds were later surveyed. Surface water occurrence is shown in Figure 2-1.

2.2.6 Surveying

The City of Seattle provided services to survey the location and elevation of all sampling wells, piezometers and surface water ponds at the Midway site. The locations and elevations of all points are presented in Appendix C.

2.3 COVER MATERIAL SEARCH

An investigative program was undertaken to determine potential sources of fine sand, silt or clay which could be used separately or combined with other granular materials to form a suitable final cover. A number of City, County and State offices were contacted concerning possible sources of final cover materials. A complete list of the information obtained is presented in Appendix D.

2.4 LABORATORY INVESTIGATION

A laboratory investigation was conducted to determine the basic geotechnical and hydrologic properties of the materials encountered during the field investigation. The laboratory testing program included the following:

- o gradation
- o compaction
- o natural moisture content
- o permeability

Laboratory tests were also conducted on samples of potential cover materials.

Individual tests are discussed in the following subsections. The results of the laboratory investigation, in conjunction with the results of the field investigation, are presented in Section 3.0 of this report.

2.4.1 Gradation

Gradation tests were not conducted on the majority of samples obtained from the drilling program, because they were not of sufficient size to be considered representative of the material encountered. Representative samples were obtained from the exposed walls in the southwest corner of the landfills. Gradation tests were conducted on these samples and samples collected from potential borrow sites for the cover material. Test were conducted in accordance with procedures outlined in ASTM D422 and D1140.

2.4.2 Compaction

Compaction tests were performed on samples taken from potential borrow materials. Harvard Miniature compaction tests were conducted according to procedures outlined in Head (1980). Certain samples were recompacted under conditions simulating placement in the field, per the recommendation of Lutton (1979); the energy was reduced to account for the anticipated lower compaction under field conditions due to the soft material underlying the compacted layer.

2.4.3 Moisture Content

Natural moisture content was determined for samples from the field exploration program. Tests were conducted according to procedures outlined in ASTM D2216.

2.4.4 Permeability

Permeability tests were conducted on recompacted samples of potential cover material. All particles larger than the #10 sieve were removed before testing. Samples were compacted directly in a permeameter at optimum moisture content based on the results of a compaction test carried out on the material. The samples were recompacted under conditions simulating placement in the field, per recommendation of Lutton (op. cit.).

Tests were conducted according to procedures outlined in Soil Testing for Engineers (Lambe, 1951).

3.0 GEOLOGIC AND HYDROLOGIC CONDITIONS

3.1 GEOLOGY

3.1.1 Regional

The current geographic features in southwestern King County are a result of the Vashon glaciation. The land mass in the vicinity of the Midway landfill, bordered by the Green River and Puget Sound, consists primarily of ground moraine deposits. These deposits are composed of compact unoxidized till, with discontinuous covers of sands and gravels.

The Midway landfill is located in a localized depression in ground moraine deposits of advance glacial outwash. These materials were deposited by proglacial streams during advance of the ice sheet. The materials can generally be described as a complex mixture of light-gray sand, sand and gravel, gravel and cobbles. It locally includes some fine sand and laminated silts and clays.

3.1.2 Site Specific

The site specific geologic conditions in the vicinity of the Midway landfill were determined from the results of the field investigation.

Generally, the stratigraphy consists of the landfill materials underlain ~~overlain~~ by a thin layer of tan and brown silts and clays. These fines were deposited during the gravel mining operation as a result of washers that were used to remove the silts and clays from the sand and gravel. Water was obtained from Lake Mead and then recycled back resulting in the silts and clays being

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deposited on the bottom. Near the end of the mining operations the natural barrier separating the gravel pit and Lake Mead was broken. Water flooded the base of the pit and some of the fine grained materials from Lake Mead were deposited at the base of the gravel pit. The fine-grained deposits are probably of limited extent and do not form a continuous layer under the landfill. In the north section of the landfill, where Lake Mead was once located, the silts and clays overlie deposits of peat. Underneath the peat deposits and the remainder of the landfill is a complex mixture of glacial outwash materials.

The glacial outwash deposits consist of material ranging from clayey sand and gravel to clean gravels, with zones of silts and clays. Along the western border of the landfill are two separate deposits of a gray silt and a silty clay. Also on the east of the landfill a thin clay pocket was intersected. There appears to be a large permeable water-bearing zone running approximately north-south beneath the center of the landfill, although existing data are insufficient to actually delineate this zone.

Figure 3-1 shows cross sections through the landfill. These sections have been drawn to intersect several of the exploration locations and generally indicate the major geologic features occurring at the landfill.

Due to the coarse nature of the glacial outwash deposits it was extremely difficult to obtain representative samples of these materials for laboratory testing. Drive tube samples that were recovered were returned to the laboratory for classification and water content testing. The results of these tests are shown on the borehole logs. Rotary drill cuttings were obtained over 5 foot intervals and were used for classification of the materials.

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Two large bulk samples were obtained from the material exposed on the south and west slopes of the old gravel pit. Grain size tests were conducted on both samples and are shown in Figure 3-2. These samples indicate a partial range of the grain sizes that are representative of the glacial outwash materials. The samples are generally well graded and contain a significant amount of silt-size material.

3.2 SURFACE WATER

3.2.1 Regional

The regional flow of surface water is controlled by the regional ground surface contours. Figure 3-3 shows ground surface contours in the vicinity of the Midway landfill with the dashed line indicating the approximate surface water divide between the Green River and Puget Sound drainages. Surface water falling in the vicinity of the Midway site will flow towards Puget Sound.

3.2.2 Site Specific

Review of aerial photographs covering the Midway site in 1936 and 1946 confirm that the landfill was located in a local depression and that there has probably never been any surface drainage off of the site. Water that collected in this area either flowed into Lake Mead, infiltrated into the groundwater or evapotranspired.

The landfill is currently serving as a drain field for surface water that is collected east of I-5. Water is conducted in two CMP culverts running under the freeway and into the landfill. Surface water ponds are located along the north and west border of the landfill and in the southwestern corner. These ponds are

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fed by both on-site and off-site surface drainage as well as from seeps in the landfill. The levels of these ponds reportedly vary considerably depending upon season of the year. Surface water infiltrating into the landfill is apparently percolating below the landfill into the regional groundwater. The water level in the pond located near the scale house on the west side of the landfill is currently being controlled by pumping excess water into the pond in the southwest corner of the landfill where it readily infiltrates into the permeable materials underlying the area. Existing culverts and the extent of surface water ponds on March 9, 1982 are shown in Figure 3-4.

3.3 GROUNDWATER

3.3.1 Regional

Approximate contours of the regional groundwater table are shown in Figure 3-5. These contours were constructed from static water levels of various wells in the area reported in Water Supply Bulletin No. 28 (Luzier, 1969). Water levels were obtained from drillers logs and were measured over a period of years from various depths and aquifer horizons. Thus, significant scatter in the readings is observed. Non-representative readings may also have resulted from water level measurements taken shortly after the wells were pumped. This may account for some of the areas of localized depression of the groundwater contours. In general, the groundwater contours follow the same pattern as the ground surface contours and indicate that there is a groundwater divide north of the Midway landfill from which water is flowing out in all directions. The landfill is located near the divide between groundwater flowing into the Green River and that flowing into Puget Sound. The data is insufficient to draw detailed groundwater contours at the Midway site but based upon measured

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water levels and surface topography, groundwater is believed to be flowing generally to the south or southwest.

3.3.2 Site Specific

Static water level elevations in all water sampling wells completed at the Midway site were measured on March 9, 1982 and are shown on Figures 3-6 and 3-7. The direction of the groundwater flow in the vicinity of the landfill is complex. Within the landfill groundwater is perched on the silt and clay layers that were identified in certain areas at the base of the landfill as indicated by static water level elevations of wells completed in the landfill shown on Figure 3-7. This perched mound is being fed by surface water from the site and east of I-5. Water from this mound is apparently percolating into the regional groundwater probably through pervious zones identified at the southern end of the landfill. Static water level elevations from wells located below or outside of the landfill indicate that there is a localized groundwater mound in the regional groundwater system along the west side of the landfill (see Figure 3-6). This is probably due to the numerous surface water ponds located in this area which are recharging the groundwater. This localized mound evidently causes groundwater on the west side of the landfill to flow eastward towards the center of the landfill and then southward out of the immediate area of the landfill. During the dry season of the year when these ponds are reduced or disappear, static groundwater levels on the west side of the landfill may drop and the gradient could turn to a southerly or southwesterly direction.

Field water quality samples were taken from each sampling well and tested for leachate indicators. The results of all field water quality tests are listed in Appendix C. Conductivity

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values, which are usually a good indicator of the presence of leachate, are shown in Figure 3-8. Conductivity readings for uncontaminated groundwater in this area are probably in the the range of 100-200 μmhos/cm. Readings greater than this probably indicate leachate contamination. The values indicate that most leachate generated from the landfill is flowing downward to the regional groundwater table and then towards the south in the direction of the regional groundwater flow. It should be noted that the direction of the groundwater flow (and leachate flow) in the vicinity of the landfill could change during the dry season of the year and that continued monitoring of water levels is required to evaluate seasonal fluctuations in flow direction.

Field permeability tests were conducted in boreholes BH-3 and BH-7 which were sealed into the glacial deposits below the landfill. The recovery of water in BH-3 was extremely slow indicating that the tip was located in low permeability material or that it may have become partially plugged. Permeabilities of 5×10^{-7} cm/sec and 4×10^{-5} cm/sec were measured for BH-7 and BH-3 respectively.

Rising head tests similar to those conducted in BH-3 and BH-7 were attempted in BH-6 and BH-8. In these larger diameter wells only a small drawdown could be obtained with the air compressor that was being used to blow out the holes. The recovery was so fast that reasonable data could not be obtained for an exact determination of the permeability. From the observed material characteristics and pumping rates that were recorded during drilling, it is estimated that the permeability may be on the order of 10^{-2} to 10^{-3} cm/sec for material intersected in BH-6 and BH-8. These values are representative of the types of materials present.

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3.4 METHANE GAS

Review of the monitoring data indicates that there are two areas of high, near-surface methane gas concentrations (see Figure 3-9). These areas are outside of any fill material, thus gas is traveling through the subsurface soil to the west. The methane gas problem was first identified in the area when Pacific Northwest Bell workmen opened a telephone vault and noticed high levels of methane gas, indicating that the gas is migrating in existing utility trenches west of the landfill. No other areas of methane gas migration have been identified or reported around the periphery of the landfill.

A large portion of the area labeled A in Figure 3-9, which contained high subsurface methane gas concentrations, is covered with impermeable asphalt or concrete. This is believed to be trapping gas underneath, forcing it to travel horizontally westward. Upon reaching Highway 99 the gas probably flows in the relatively more pervious backfill of utility trenches, running along the highway, to the area labeled B. Storm drainage lines have been identified running across Highway 99 in this area.

Three wells were completed to detect any deep migration of methane gas at the locations shown in Figure 2-1. Monitoring in these wells has not indicated any presence of deep methane gas migration, thus enforcing the observation that gas migration is directly beneath the asphalt and cement.

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4.0 ELEMENTS OF A CONCEPTUAL CLOSURE DESIGN

4.1 REGULATORY REQUIREMENTS

Municipal solid waste landfills should not contain substances or characteristics which would classify them as hazardous waste under the Federal Resource Conservation and Recovery Act (RCRA) or as dangerous waste under the State of Washington Dangerous Waste Regulations WAC 173-303. Therefore it is assumed, for the purpose of this study, that Midway is not a dangerous or hazardous waste site. It is not clear whether the site will have to be specifically tested for hazardous waste characteristics of ignitability, corrosivity, reactivity and EP toxicity as defined in RCRA and WAC 173-303.

Relatively few specific regulatory requirements pertain to groundwater monitoring at solid waste sites. Under RCRA, the EPA has published criteria in the Federal Register (FR) September 13, 1979 for classifying facilities as either sanitary landfills or open dumps. Groundwater criteria specify that "A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary . . . " The term "underground drinking water source" applies to any aquifer supplying drinking water for human consumption or any aquifer containing groundwater with less than 10,000 mg/l total dissolved solids. Under the latter definition the groundwater in the Midway area would be considered a drinking water source and thus contamination should not extend beyond the property boundary.

State and County regulatory requirements governing landfill operation and closure are outlined in State of Washington regulations relating to Minimum Functional Standards for Solid Waste Handling, WAC 173-301 and King County Board of Health Rules and Regulations Establishing Minimum Functional Standards for Solid Waste Handling; Prohibiting Certain Conduct, Number VIII. Applicable state and county requirements are listed below.

- Plans for a sanitary landfill shall include provisions for interception and treatment of leachate at all sites where the average annual precipitation is 25 inches or more. Interception and treatment may be required at other sites. Plans and specifications for leachate collection and treatment must be submitted to and be approved by the Department of Ecology and an application for a waste discharge permit be submitted where applicable. It shall be the responsibility of the operator to develop a sampling and testing program for leachate approved by the Seattle-King County Health Department.

- The distance separating the groundwater table from the bottom of a sanitary landfill disposing of readily decomposable organic waste and hazardous wastes shall be determined on a case-by-case basis. Generally a separation equivalent to four (4) feet of impervious soil shall be the minimum separation between the bottom of the fill and the highest groundwater.

- Provision shall be made for adequate venting or redirecting of gases generated by solid waste, if conditions require. It shall be the responsibility of the operator to develop a sampling and testing program to monitor gas production approved by the Seattle-King County Department of Public Health.

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- As soon as possible after reaching the final lift of a given area of a site, the area shall be covered with an equivalent of two (2) feet of compacted soil adequately sloped to allow surface water to run off.

- The finished surface of the filled area shall be covered with adequate tillable soil and seeded with native grasses or other suitable vegetation immediately upon completion, or as soon as conditions permit. If necessary, slopes shall be covered with straw or other mulch to prevent erosion, both before and after seeding. Final grades shall conform to those specified in the approved design plan. Proposed revisions of the original design plan shall be submitted to the Health Officer for approval.

- At the completion of the final cover of a sanitary landfill, the Seattle-King County Department of Public Health shall be notified at least thirty (30) days in advance in order that a site investigation may be conducted before earth-moving equipment is removed from the property. Maintenance shall be conducted by the owner of this site at the time of the abandonment and/or completion until the fill becomes stabilized or for a minimum of five (5) years. Necessary leveling and repairs shall be made.

- Maps and a statement of fact concerning the disposal area shall be recorded as part of the deed with the County Department of Records and Elections not later than three (3) months after the completion of operations. Records and plans specifying materials, location, and periods of operation shall be available for inspection. Areas used for the disposal of wastes shall not be sold or transferred without advanced notification of the Seattle-King County Department of Public Health.

The King County Health Department and the Washington Department of Ecology have enforcement power over the regulations but it is uncertain to what extent these agencies will require remedial measures to be taken at the Midway site. We have developed various conceptual closure design elements and recommendations which are intended to satisfy the regulatory requirements concerning:

- Surface water management
- Leachate/groundwater management
- Methane gas management
- Final grade contours.

The particular elements that are incorporated into the final closure system at the Midway landfill will depend on a number of factors including regulatory requirements, final land use and cost.

4.2 SURFACE WATER MANAGEMENT

The control of surface water runoff is currently a major problem at the Midway site. Poor drainage patterns allow ponding and infiltration, of on-site runoff, into the fill. Surface runoff from east of I-5 is directly injected into the landfill by subsurface drains. These practices contribute to leachate production and migration. As part of the closure plan, an effective surface water management system must be developed which provides adequate drainage and release of surface water and

DRAFT

prevents infiltration into the landfill. This will probably involve appropriate grading of the landfill to provide drainage, construction of on-site retention facilities, construction of on-site and off-site drainage pipes or channels, and elimination of the drainfield for water originating east of I-5. It is understood that specific recommendations for surface water management will be developed for the final closure plan.

The major geotechnical concern regarding surface water management is the elimination of infiltration into the landfill since this serves to generate leachate. Measures to accomplish this include contour grading of the site and placement of a soil cover. Details of these measures are discussed further in Sections 4.4 and 4.5, respectively.

4.3 LEACHATE/GROUNDWATER MANAGEMENT

With effective control of the surface water at the site the amount of leachate generated in the landfill can be significantly reduced. Evidence indicates that the landfill materials are not in contact with the regional groundwater table. Therefore, the major source of leachate, after steady-state post-closure conditions have been reached, is likely to be surface water infiltrating the cover. Various conceptual design elements for the reduction of leachate generation, collection of leachate, and interception of groundwater are presented below. These design elements represent various levels of effort in the control of existing and future leachate. The particular system chosen at the Midway landfill will depend upon regulatory requirements, final land use and cost.

DRAFT

4.3.1 Soil Cover

Placement of a cover is intended to restrict the quantity of surface water infiltrating the landfill and thus reduce leachate production. As a minimum requirement, the landfill should be capped with at least two feet of compacted soil, or equivalent. The cover should consist of a relatively low permeability compacted soil layer overlain by topsoil and a vegetative cover. It should be embedded at least two feet into the natural soils surrounding the landfill. Generally, a final soil cover will consist of clayey to silty sands. These materials are well suited for a final cover because they retard infiltration, are resistant to wind and surface water erosion, are plastic enough to accommodate settlements with limited maintenance, and are fertile enough to sustain vegetation. The specific design of a soil cover and availability of materials are addressed in Section 4.5.

4.3.1.1 Leachate Production

A compacted soil cover, as is recommended, will not provide a completely impermeable barrier to infiltration. Therefore, an estimate of infiltration through the cover into the landfill has been made to assess potential quantities of leachate production.

The hydrologic system existing after placement of a soil cover is conceptually shown in Figure 4-1. Water is provided to the landfill by precipitation and lost by surface runoff, evapotranspiration and infiltration through the landfill into the groundwater. Once in the landfill, water will flow vertically until encountering either low permeability layers within or at the base of the landfill. Water not intercepted by these layers will infiltrate the regional groundwater.

DRAFT

A water balance method was used to estimate infiltration, the details of which are provided in Appendix E. For the anticipated range of cover permeabilities, 10^{-6} to 10^{-7} cm/sec, the volume of annual infiltration through the cover ranges from approximately 14.8 to 1.5 acre-feet.

The above quantities of leachate production are only estimates. Variations in cover characteristics, vegetation, precipitation and other factors will significantly affect the net quantity of leachate produced in the landfill.

4.3.2 Leachate Collection

In addition to a soil cover, a further reduction in the quantity of leachate reaching the groundwater could be accomplished by a system designed to collect a portion of the leachate. Leachate will tend to accumulate in the two low areas of the landfill at the base of the old gravel pit and Lake Mead (see Figure 4-2). Infiltration into the groundwater will be inhibited by the low permeability peat and clay deposits that were identified in these areas. Wells placed at the top of these low permeable materials could be pumped as necessary to maintain the perched leachate levels as low as possible, thus reducing infiltration into the groundwater.

Based on current information as to the extent and depth of the leachate in the landfill and assuming an effective porosity for the landfill materials of 0.3, it is estimated that a drainable volume of 300 acre-feet of leachate exists within the landfill. Due to the limited lateral extent of these low permeability layers (see Figure 4-2), not all of the existing leachate could be removed by this system. A portion of the future leachate generation, which is estimated to be between 14.8 and 1.5

DRAFT

acre-feet yearly (depending on cover permeability) could be removed by periodic pumping. This system would probably not intercept and remove all of the leachate in the landfill or that generated by infiltration but would significantly reduce the amount reaching the regional groundwater.

For the purpose of a conceptual design we have assumed that a series of three wells located approximately as shown in Figure 4-2 would be used to remove leachate in the landfill. Water levels in these wells along with other piezometers located in the landfill should be monitored regularly. When water levels reach some predetermined level the wells should be pumped utilizing appropriate submersible pumps lowered down each well. Leachate removed from these wells will require treatment before being discharged.

In order to provide a detailed design of such a system, further investigations would be required to determine the aerial extent of the clay and peat deposits, the depth to the top of these deposits over their areal aerial extent, and the permeability characteristic of the landfill materials. This information could be obtained from additional boreholes possibly combined with geophysical surveys and pumping tests.

4.3.3 Groundwater Interception

If the City is required to eliminate or control all the leachate leaving the site, then techniques for intercepting the groundwater should be incorporated into the final closure plan. Techniques which might be considered include the following:

- o Cut-off walls
- o Bottom sealing
- o Deep well dewatering.

DRAFT

Various cut-off wall systems, which include bentonite slurry trenches, grout curtains and sheet piling, are sometimes used to divert groundwater. Usually these walls are embedded in some impervious material below the landfill. At the Midway site there is no evidence of a continuous impervious material underlying the site at a depth practical for construction of a cut-off wall. Thus, a cut-off wall probably is not a viable alternative at Midway.

Bottom sealing is an alternative which involves creating a bowl-shaped bottom seal beneath the site to isolate the landfill from the groundwater. The seal is constructed by pumping or pressure-injecting grout under the existing landfill through tubes placed through the fill at regular intervals.

Although bottom sealing may theoretically be a feasible alternative for groundwater interception, there are many technical and economic reasons why it is not considered viable at the Midway site. The silty to clayey material encountered below the landfill would make grout injection very difficult also there is no way to positively determine if an effective seal has been formed under the landfill. Even if the technical problems were overcome, it is not considered to be a cost-effective solution when compared to others (Tolman, 1978).

A more cost effective alternative for intercepting the groundwater is deep well interception. This consists of placing extraction wells down-gradient of the landfill (see Figure 4-3) to intercept any groundwater contaminated with leachate. This would require continuous pumping and treatment of large volumes of water.

DRAFT

A further hydrogeologic evaluation of the aquifer, including aquifer testing, would be required before a deep well system could be designed. Based on the regional groundwater flow, a series of these wells (the number, spacing and pump rates to be determined from further investigations) could be installed on the south end of the landfill.

A benefit of this system is that by reversing the gradient at the south end of the landfill, water south of the fill would be flowing back toward the wells. This would locally reverse the direction of the plume migration and could remove some of the existing leachate that has migrated out of the site.

4.4 METHANE GAS MANAGEMENT

Methane gas has been found to be migrating off-site along the western boundary of the landfill and the potential for migration elsewhere around the landfill exists. Therefore, it will be necessary to incorporate a methane gas collection system into the final closure system. Recommendations concerning a gas collection system are intended to:

- Provide an interim system that would intercept the observed gas migration west of the landfill and could be installed prior to closure

- Provide a permanent system for collection and venting of methane gas that would incorporate the interim system.

For control of methane gas that has been observed west of the landfill Golder Associates has previously recommended that a gravel-filled interceptor trench approximately 15 feet deep be placed along the west and north side of the landfill as shown in

Figure 4-4 (letter to Parametrix, Inc., dated March 3, 1982, see Appendix F). Due to the urgency of the problem of methane gas migration, portions of this interceptor trench will probably be constructed before final closure. Surface water ponds in the northwest corner and along the north side will prevent construction of the trench in these areas until surface drainage is provided.

In the southwest corner little or no filling has taken place to date. A gravel interceptor wall should be constructed between the existing natural materials and the fill as it is placed. This will act as an interceptor of methane gas and should be connected to the other methane gas interceptor trench when filling is completed.

For controlled collection of methane gas venting out of the landfill we recommend placement of a layer of permeable, coarse, granular material immediately under the entire final cover. This would include a network of gravel-filled trenches and collection pipes to conduct the gas to topographic highs where it could be burned, vented or collected (see Figure 4-4).

Since final contours of the site have not been determined, existing contours have been used for the conceptual design of the gas collection system. The only major change in this basic plan that would be required by a change in the contours would be that the collection points would be moved to the new topographic highs. Cross sections through a typical collection trench and an interceptor trench are also shown in Figure 4-4. Depending on the type of system and the number and location of vents/ collection points, it may be necessary to apply negative pressure (suction) to remove the gas.

An alternative methane collection system would consist of methane collection wells, drilled at sufficient spacing to vent the buildup of methane beneath the cover. However, it is considered that these wells would not tolerate deflections to the extent that flexible pipe would, thus long-term maintenance would be more difficult.

We understand that studies are being conducted by representatives of the land owners to determine the feasibility of collecting methane generated at the landfill for commercial use. These studies were not available for this report. The conceptual methane gas management system presented herein will centralize the gas collection points and could probably be incorporated into a commercial recovery system. However, significant changes may be required depending upon the final design of a commercial system. If commercial recovery is not utilized, then methane must be either vented or burned in a controlled manner.

The field investigation did not identify any deep off-site gas migration. However, if the monitoring program discussed in Section 5.0 reveals any deep migration, then deep withdrawal wells may have to be installed to intercept this gas if it presents a serious hazard.

4.5 FINAL GRADE CONTOURS

We understand that discussions are currently taking place between the City of Seattle, the City of Kent and the landowners concerning the final contours of the site. Thus, in our analyses we have assumed that existing contours are representative of the contours at closure.

Contour grading of the landfill is a simple and effective means for controlling surface infiltration. Grading the landfill to a profile of a maximum of 12 percent and a minimum of 6 percent with side slopes no steeper than 20 to 25 percent will allow surface water to drain from the site and will minimize infiltration (Tolman, 1978). If the minimum slopes are not compatible with the intended final landuse, then subsurface drains may be required to control infiltration. The final surface configuration of the landfill should be designed to permit drainage even after settlement of the fill (estimated to be up to 25%). It may be necessary to continually maintain the surface grade during the first 5 to 10 years after closure when the settlement will be greatest.

Final landuse at the Midway landfill should incorporate recommendations for contour grading of the site, allow for expected settlements and periodic maintenance, and accommodate the methane collection system.

4.6 FINAL COVER DESIGN

Various artificial and natural materials can be used as a final cover. Impervious covers such as concrete, asphalt and synthetic liners are very expensive and would typically only be required when the toxicity level of the waste material is extremely dangerous to public health (Kastman, 1981). At Midway a soil cover system consisting of a low-permeability cover material which is overlain by topsoil and a vegetative cover should be sufficient. The low-permeability cover material should be a clayey sand to sandy silt. The compacted cover should have a maximum in-place permeability of 10^{-6} cm/sec, with values of 10^{-7} cm/sec being more desirable.

The soil cover should be placed over the existing soil cover which is now in place and should be compacted to a thickness of from two to three feet. Generally, the more plastic the material, the thinner the cover can be. Topsoil should be in addition to this thickness. It is estimated that between 0.2 to 0.3 million cubic yards of material will be necessary to cover the 59 acres of the landfill.

It should be recognized that special procedures may have to be developed by the contractor during construction in order to obtain proper compaction of the cover materials due to lack of resistance from the underlying fill materials. The cover should be embedded at least two feet into the surrounding natural soils around the perimeter of the landfill.

An investigation was undertaken to determine the availability of suitable cover material in the vicinity of the Midway landfill. Various State, County, and City agencies were contacted concerning the availability of suitable cover material. The details of the information obtained from these agencies is presented in Appendix D. Large quantities of potentially locally available material suitable as a final cover were identified. These include:

- waste from the Mt. Baker tunnel excavation
- waste from the Metro tunnel excavation
- waste from downtown Seattle building site excavations
- material from geologically unstable areas (i.e., landslides).

However, numerous deposits of coarse-grained glacial material are available which, if combined with silt or clay, may be suitable as a final cover.

DRAFT

Three samples of material from an abandoned sand and gravel operation located near the Midway landfill (see Figure 4-5) were obtained and tested to determine their feasibility as a final cover. Figure 4-6 shows the grain size curves for the three samples and Figure 4-7 shows the compaction curves for the samples with the material greater than the number 10 sieve removed. Permeability tests were conducted on samples of this material and results are listed in Table 4-1.

Table 4-1
Permeability and Compaction Test Results

Test	S-1	S-2	S-3	Combined Sample(3)
Maximum Dry Density (PCF) Normal Energy(1)	106.5	115.0	110.5	---
Optimum Water Content(%)	14.3	15.8	15.0	14.5
Maximum Dry Density (PCF) Reduced Energy(2)	101.1	111.8	101.4	118.2
Measured Permeability Reduced Energy(2) (cm/sec)	7.0×10^{-6}	2.3×10^{-6}	1.0×10^{-5}	2.2×10^{-8}

(1) Harvard Miniature - 5 layers, 20 blows/layer
(2) Harvard Miniature - 8 layers, 5 blows/layer
(3) 60% sand (S-3) - 40% clayey silt.

The permeability samples were recompacted at optimum moisture content based on compaction test results under conditions simulating placement in the field, per the recommendations of Lutton (1979); that is, the energy was reduced to account for the anticipated lower compaction under field conditions due to the soft material underlying the compacted layer. Due to the high permeability values for these samples, it is apparent that the unmixed samples alone would not be suitable as a low permeability final cover.

DRAFT

In the Seattle area there are significant deposits of silty clay to clayey silt which are locally called Lawton Clays. Thus we feel that it is feasible to obtain significant quantities of this fine-grained material to combine with more locally available coarse-grained materials to comprise a suitable final cover.

A sample of this coarse-grained material was combined with a clayey silt obtained from a downtown Seattle excavation to determine if a combination of these materials could produce a suitable final cover. The results of a grain size analysis test and Atterberg Limits test on the clayey silt are shown on Figure 4-8. A sample was mixed of 60 percent sand and 40 percent clayey silt. The results of a compaction test and grain size analysis are shown in Figure 4-9. A permeability of 2.2×10^{-8} cm/sec was measured for a sample compacted at optimum moisture content and reduced energy. Atterberg Limit tests indicate a plasticity index of 11. A material of this permeability and plasticity could be used as a final cover.

Per discussions with State, City and County officials, the material from various construction sites is available only during a relatively short excavation period. Two alternatives are available to the City: (1) the City can begin actively searching for this material and set aside an area where it could be stock-piled until construction of the cover is initiated; or (2) the City can delay looking for specific material until the landfill is closed and then material obtained could be placed directly on the landfill.

When specific deposits have been identified for final cover material, further tests should be conducted to determine compaction and permeability characteristics and the required thickness. If materials were to be combined to form the final

DRAFT

cover, then further tests would be required to determine mixture quantities.

It is anticipated that any soil cover placed on the landfill will require periodic maintenance. This maintenance would include regrading of localized depressions and repair of cracks which would allow surface water infiltration. Maintenance would be required until the settlements have slowed or ceased.

5.0 MONITORING PROGRAM

Recommendations for various monitoring programs at the Midway site are given below. Monitoring of groundwater quality and settlement of the fill are discussed in detail. Monitoring of surface water and methane gas will be addressed in more detail in the final closure plan.

5.1 SURFACE WATER

A detailed assessment of the surface water monitoring program is not possible until various technical and legal issues regarding the discharge and disposal of surface water from the Midway site are resolved. These include allowable release rates and discharge points. In general, surface water quality should be regularly monitored to determine if it is being adversely affected by the landfill after closure. Specific details of the monitoring program should be worked out with the Washington Department of Ecology (WDOE) and the Health Department.

Surface water should be monitored at any location where it discharges from the site. It is expected that both semi-annually and monthly sampling and analysis of surface water for basic leachate indicators will be required. More complete chemical analysis is recommended initially after closure and then on an annual basis.

5.2 GROUNDWATER

5.2.1 Regulatory Requirements

The WDOE has developed minimum functional standards for solid waste sites. The standards basically require that landfills do

DRAFT

not pollute groundwater. Although specific water quality standards are not given, it is expected that maximum contaminant levels in Table 5-1 along with primary and secondary drinking water standards listed in Table 5-2 will be used in developing a groundwater monitoring program.

Table 5-1
Maximum Contaminant Levels Under
EPA Solid Waste Classification Criteria

1. Maximum contaminant levels for inorganic chemicals

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.0
Selenium	0.01
Silver	0.05

The maximum contaminant levels for fluoride are:

Temperature(1) degrees Fahrenheit	Degrees Celsius	Level (milligrams) per liter
53.7 and below	12 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

(1) Annual average of the maximum daily air temperature.

2. Maximum contaminant levels for organic chemicals.

	Level (milligrams per liter)
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene)	0.0002
Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl) ehtane)	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67 to 69 percent chlorine)	0.005
(b) Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxy-acetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	0.01

DRAFT

Table 5-2
Primary and Secondary Drinking Water Standards
(National Primary and Secondary Drinking Water Regulations - EPA)

Constituent	Maximum Contaminant Levels
1. Primary Standards	
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg/l
Lead	0.05 mg/l
Mercury	0.002 mg/l
Nitrate as N	10.0 mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l
Fluoride	1.4 to 2.4 mg/l (temp. dependent)
Endrin	0.0002 mg/l
Lindane	0.004 mg/l
Methoxychlor	0.1 mg/l
Toxaphene	0.005 mg/l
2,4-D	0.1 mg/l
2,4,5-TP Silver	0.01 mg/l
2. Secondary Standards	
Chloride	250 mg/l
Color	15 color units
Copper	1.0 mg/l
Corrosivity	noncorrosive
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor number
pH	6.5 to 8.5
Sulfate	250 mg/l
Sodium	20 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Zinc	5 mg/l

Evidence indicates that groundwater below and adjacent to the Midway landfill has been polluted by leachate. The published requirements for mitigation of existing leachate are applicable to operating landfills. It is not certain how these requirements will be applied to a landfill after closure.

The problem of existing groundwater pollution must ultimately be resolved by discussions between the City of Seattle and the appropriate regulatory agencies. It is expected that monitoring of existing pollution will be a minimum requirement.

5.2.2 Monitor Well Locations

WDOE standards require at least one upgradient and two downgradient monitor wells. Recommended locations of monitor wells are shown in Figure 5-1. This array will provide upgradient and downgradient monitoring at the site. The existing sampling wells in hole BH-6 and BH-8 can be used as monitor wells. Three new monitor wells are recommended: one approximately 300 feet north of the fill to monitor upgradient quality; one southeast of the site; one approximately 600 feet south of the site. More wells may be required in the future depending upon the data collected from the five monitor wells recommended herein.

Piezometers installed as part of the initial site investigation should continue to be monitored. These installations will provide useful information pertaining to water levels, water quality and cover performance and should be monitored regularly.

5.2.3 Monitor Well Construction

Monitor wells should be constructed to comply with regulatory standards and guidelines including:

- Well casing and screen should be made of a relatively non-reactive material. PVC is generally acceptable, most metals are not;

- PVC solvent or cement should not be used for plastic well casing and screen;

- Wells should be drilled using air, water, or a biodegradable mud as the circulating fluid, and should be properly developed to remove any contamination introduced during drilling;

- The annulus of each well should be sealed to prevent surface water inflow;

- The top of each well should be equipped with a locking cover.

Wells at dangerous waste sites are required to be a minimum of 4 inches in diameter to allow easy sample collection. Size requirements at municipal landfills are uncertain. The WDOE has indicated that smaller wells (e.g., 2 inches) may be acceptable if devices are provided which can sample small diameter wells.

A schematic of a typical monitor well is shown in Figure 5-2. Proposed methods of monitor well construction should be approved by the WDOE before wells are actually installed.

5.2.4 Water Sampling and Analysis

Water samples can be taken by bailing or pumping the monitor wells. The sampling device should be thoroughly cleaned before use and should be constructed of materials which will not chemically alter the sample.

Prior to collecting a water sample, a minimum of three well volumes of water should be removed from the well. If the well is in low yield materials, it is generally sufficient to pump the well dry once and let it refill before collecting the sample. As water is removed from the well its temperature, conductivity and pH should be checked periodically. These parameters should stabilize before collecting a sample.

Sampling procedures should be established in cooperation with the laboratory responsible for the chemical analysis. Generally the laboratory can provide sample bottles with preservatives already added. Chemical analyses should be conducted by an EPA certified laboratory.

Semi-annual sampling of monitor wells should be sufficient although a final determination of sample frequency should be made in coordination with the WDOE.

It is recommended that initially a complete chemical analysis of each well be made which will establish conditions at closure. Thereafter it should be sufficient to analyze only for major leachate indicators. If significant increases in indicators are noted more complete analysis may be required. A representative list of chemical constituents is given in Table 5-3. The final list should be developed in cooperation with WDOE.

Table 5-3
Recommended Groundwater Analysis

1. Parameters Analyzed Semiannually

Temperature	Chloride
pH	Iron
Conductivity	COD
Color	TDS
Turbidity	TSS

2. Additional Parameters Analyzed Initially

Hardness	Arsenic	TOC
Alkalinity	Barium	BOD
Acidity	Cadmium	*Chlorinated Hydrocarbons
Phosphate	Chromium	**Chlorophenoxys
Sulfate	Copper	
Ammonia as N	Lead	
Nitrate as N	Manganese	
Nitrite as N	Mercury	
Sodium	Selenium	
Fluoride	Silver	
Calcium	Zinc	
Odor	Cyanide	
Potassium	Foaming Agents	
Magnesium		

* Endrin, Lindane, Methoxychlor, Toxaphene
** 2,4-D, 2,4,5-TP Silver

5.3 METHANE GAS

The EPA, in their Criteria for Classification of Solid Waste Disposal Facilities (FR September 13, 1979), state that the concentration of explosive gases should not exceed:

- o Twenty-five percent of the lower explosive limit for gases in facility structures (excluding gas control or recovery systems);

DRAFT

- The lower explosive limit for gases in soil at the property boundary. (The lower explosive limit for methane gas in air is about 4 percent by volume.)

These are criteria, not regulations, and thus are not specific requirements for a closure system.

The closure system will incorporate a methane gas collection and management system which will be designed to prevent offsite migration through the ground. However, it is not possible to guarantee 100 percent methane collection, thus a gas monitoring system should be established.

Figure 5-3 shows possible locations of gas monitor wells on the periphery of the site. Note that two gas wells installed as part of the site investigation could be utilized for monitoring methane. Figure 5-4 shows a typical gas monitor well design. Any final designs for a gas monitor well system should be developed in cooperation with WDOE and the Health Department.

5.4 SETTLEMENT

Decomposition and consolidation of the landfill will result in significant settlements. It is not possible to predict the amount of settlement. However, it is useful to monitor settlement in order to mitigate adverse affects (such as altered surface drainage, cracking of cover material) and to project long term trends.

An annual aerial topographic survey would provide the desired information. If annual aerial surveys are not practical due to cost or other considerations, settlement should be monitored by setting up approximately 12 monitor stations on the landfill.

DRAFT

Locations should be chosen once final contours and land use are determined. Each station would typically consist of a 2 foot by 2 foot steel-reinforced concrete block, about 12 inches thick and buried at least several inches into the ground. The elevations of each station should be surveyed at least once a year.

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The stratigraphy at the site consists of the landfill materials underlain by glacial outwash deposits. These deposits consist primarily of permeable sand and gravels with some silt, cobbles and boulders. Locally they contain deposits of silts and clays.

2. Currently, offsite surface water from east of Interstate-5 is being conducted into the landfill and onsite surface water is being collected in various ponds around the site. Due to the large amount of surface water entering the landfill, a perched groundwater mound containing leachate has formed in the landfill. This leachate is ultimately infiltrating the groundwater.

3. Gradients indicate that the groundwater flow direction at the site is predominantly to the south. This direction may be influenced by the perched groundwater mound in the landfill and the surface water ponds around the landfill, and may change direction after closure or during dry seasons of the year.

4. Various conceptual design elements for the closure of the landfill are presented in Section 4. They include placement of a soil cover, methane gas venting/collection, leachate collection, bottom sealing and/or groundwater interception. As a minimum, we recommend that offsite surface water be rerouted around the landfill, the landfill be graded to allow adequate onsite surface water runoff, and a low permeability soil cover be placed over the landfill. This will reduce

DRAFT

the amount of leachate entering the groundwater. A gas collection system should be placed underneath the cover to collect and vent any methane gas generated. Various methane gas cutoff trenches will be needed to intercept gas that is migrating to the west, off of the site. Details of these systems are presented in Section 4.0.

5. Depending on the particular elements chosen for the closure system, further detailed geohydrologic studies may be necessary (i.e., pump tests, more boreholes, etc.).

6. Chemical water quality analyses are needed to assess the level of leachate contamination.

7. A long-term monitoring program should be implemented which includes periodic analysis of surface water and groundwater which exit the site. Monitoring should also include methane gas migration and settlement of the landfill. A suggested monitoring plan and schedule are presented in Section 5.0. It is recommended that the extent of the existing plume should be determined and monitored.

REFERENCES

Brunner, Dirk R. and Daniel J. Keller, 1972, Sanitary Landfill Design and Operation, U.S. Environmental Protection Agency. SE-287.

Environmental Protection Agency, 1979. National Secondary Drinking Water Regulations. Federal Register, Vol. 44, No. 140.

Environmental Protection Agency, 1979. Criteria for Classification of Solid Waste Disposal Facilities and Practices; Final, Interim Final, and Proposed Regulations, Federal Register, Vol. 44, No. 179.

Environmental Protection Agency, 1975 and 1976. National Interim Primary Drinking Water Regulations. Federal Register, Vol. 40, No. 248 and Vol. 41, No. 133.

Head, K.H., 1980. Manual of Soil Laboratory Testing, Vol. 1, Pentech Press.

Kastman, Kenneth H., 1981. Remedial Actions for Waste Disposal Sites. Fourth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, pp. 131-150. Madison WI., Department of Engineering and Applied Sciences Unviersity of Wisconsin - Extension.

King County Board of Health. Rules and Regulations establishing Minimum Functional Standards for Solid Waste Handling; Prohibiting Certain Conduct. Seattle, WA, KCBH.

King County Department of Public Works, Division of Hydraulics, May, 1979. Storm Drainage Control; Requirements and Guidelines. Seattle, WA, KCDPW.

Lambe, T.W., 1951. Soil Testing for Engineers, New York, N.Y., John Wiley and Sons, Inc.

Lutton, R.J., et al., 1979. Design and Construction of Covers for Solid Waste Landfills. U.S. Environmental Protection Agency. EPA-600/2-79-165.

Luzier, J.B., 1969. Geology and Groundwater Resources of Southwestern King County, Washington. Department of Water Resources, Olympia, Washington.

Richardson, J.W., Bingham J.W., and Madison, R.W., 1968. Water Resources of King County. U.S.G.S. Water Supply Paper 1852, U.S. Government Printing Office, Washington D.C.

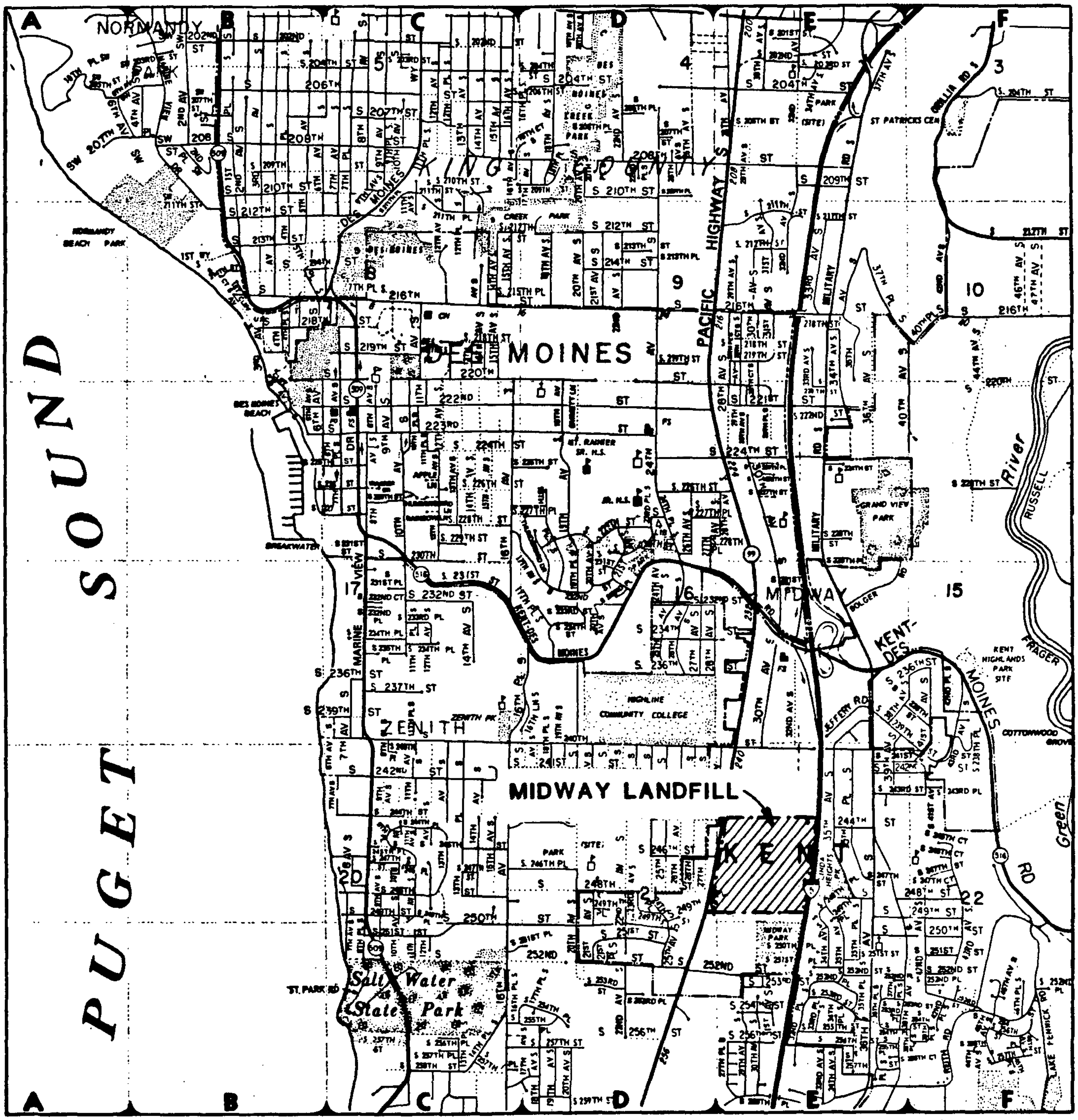
Snyder, D.E., P.S. Gale and R.F. Pringle, 1973. Soil Survey King County Area, Washington, U.S. Department of Agriculture Soil Conservation Service in Cooperation with Washington Agricultural Experimental Station.

Tolman, Andrews L., et al., 1978. Guidance Manual for Minimizing Pollution from Waste Disposal Sites, U.S. Environmental Protection Agency. EPA-600/2-78-142.

Washington State, 12/31/72. Washington Adminstration Code, Regulations Relating to Minimum Functional Standards for Solid Waste Handling, Chapter 173-301.

LOCATION PLAN – MIDWAY LANDFILL

Figure 1-1



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Scale, miles

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FIG 2-1


E 8500
E 9000
N 12500
N 12000
N 11500
N 11000
N 10500
N 10000
E 9500
Highway 99
PAVED
CONC
CONCRETE
SCALE
BH-1B
BH-1
BH-8
BH-2
B
C'
C
1
2
4
5
8
9
10
11
12
13
14
15
16
18
19
330
350
360
370
380
LEGEND
BH-6 Borehole and Groundwater Sampling Well
9 Gas Sampling Well
Piez. A Existing Piezometer
BH-2 Borehole and Deep Gas Sampling Wells
A A' Cross-Section Lines
Water Seeps
Surface Water
Reference: Taken fr

topo of Midway Landfill Site, provided by City of Seattle Engineering Departme

A'
BH-3
BH-4
BH-5
BH-7
360
370
380
390
400

CITY OF SEATTLE
MIDWAY LANDFILL

BOREHOLE AND METHANE GAS SAMPLING WELL LOCATION PLAN

Golder Associates | Figure 2-1

MIDWAY LANDFILL CROSS SECTIONS
A-A′, B-B′, & C-C′

Figure 3-1

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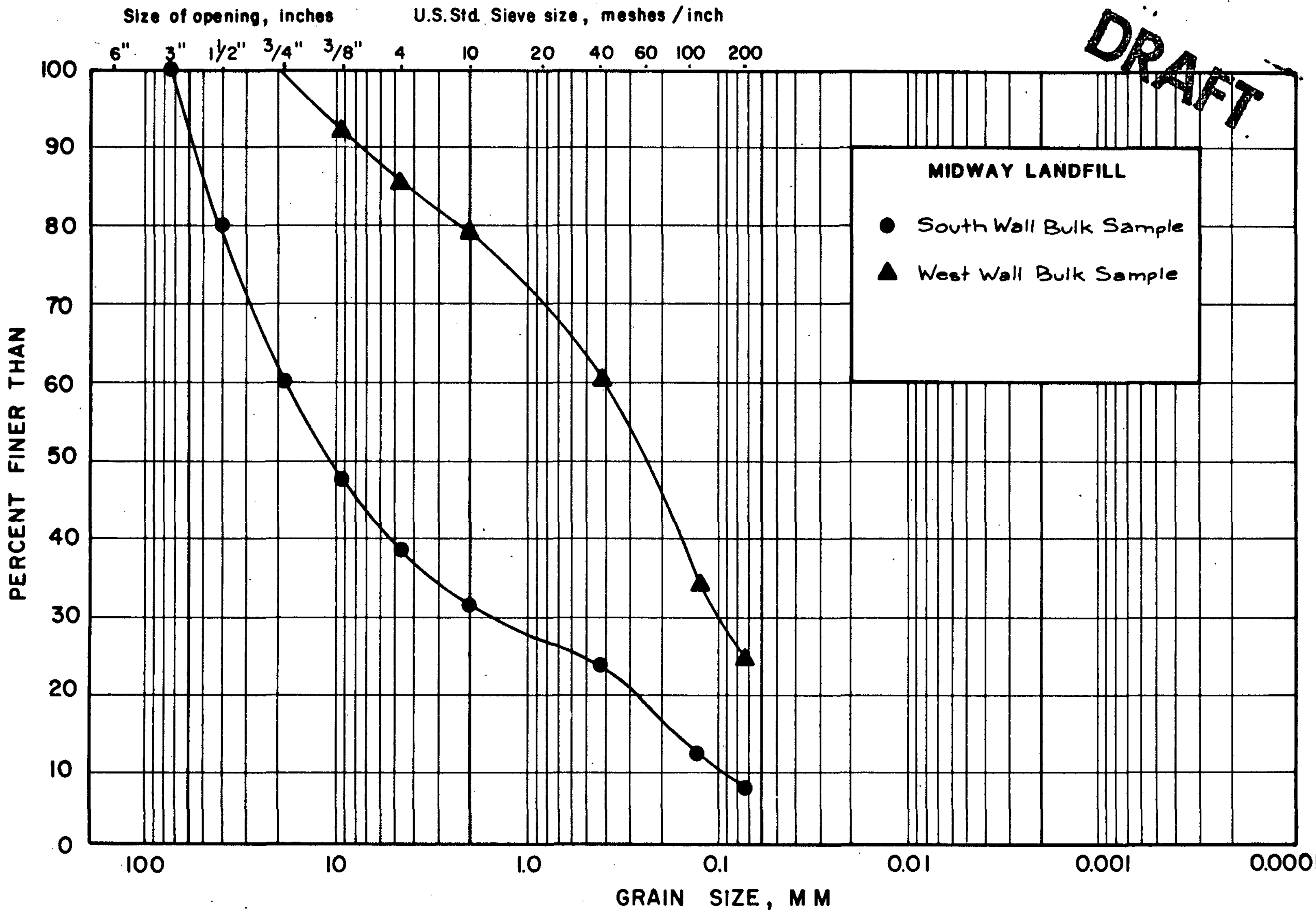

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

GRAIN SIZE DISTRIBUTION BULK SAMPLES

Figure 3-2

Project No. A813-1276-016
Project Midway Landfill

Golder Associates

Date 2-24-82
By DSM

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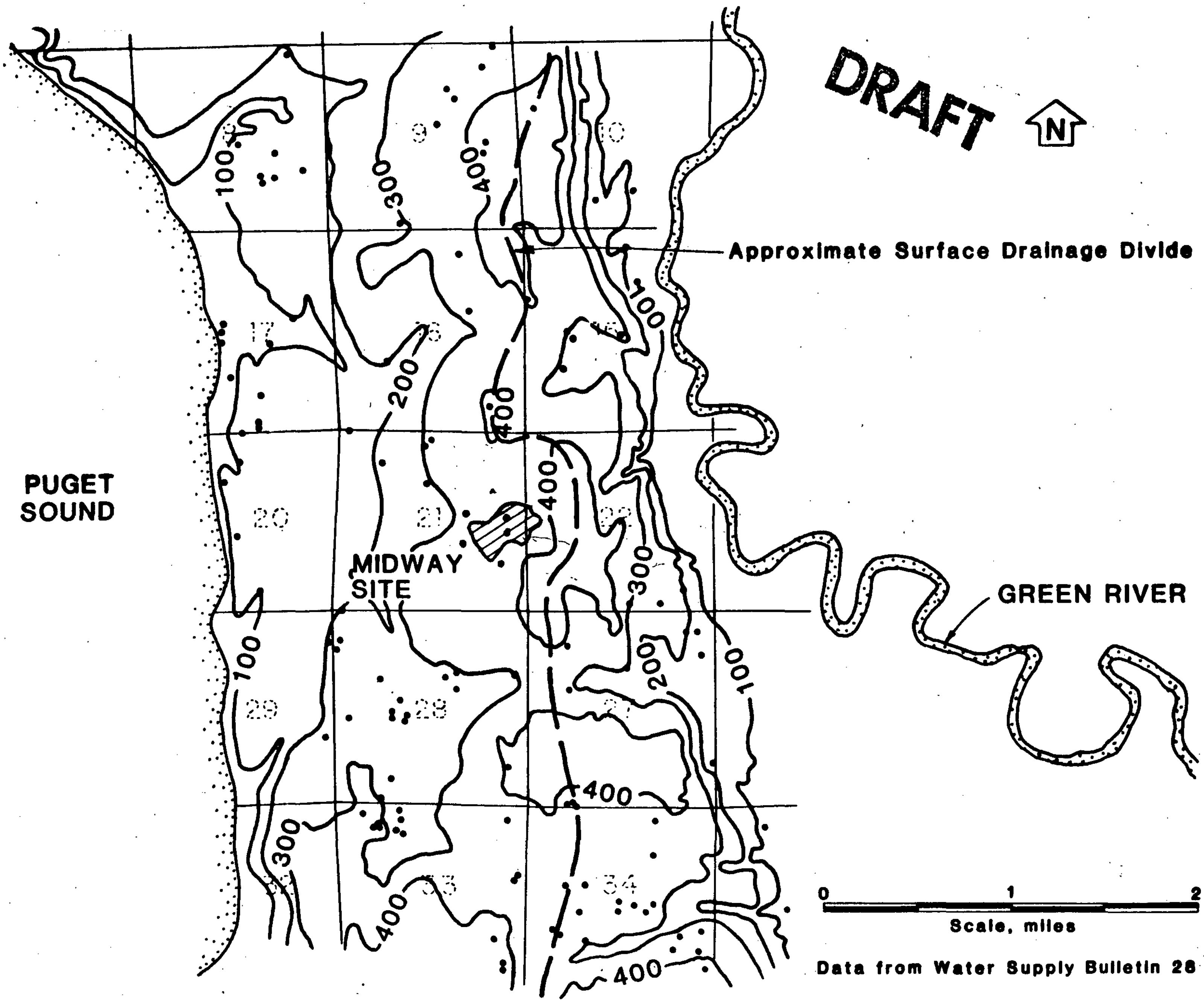
Dwg. No. A815-1276-017 Date Apr 82 Eng. P.C.



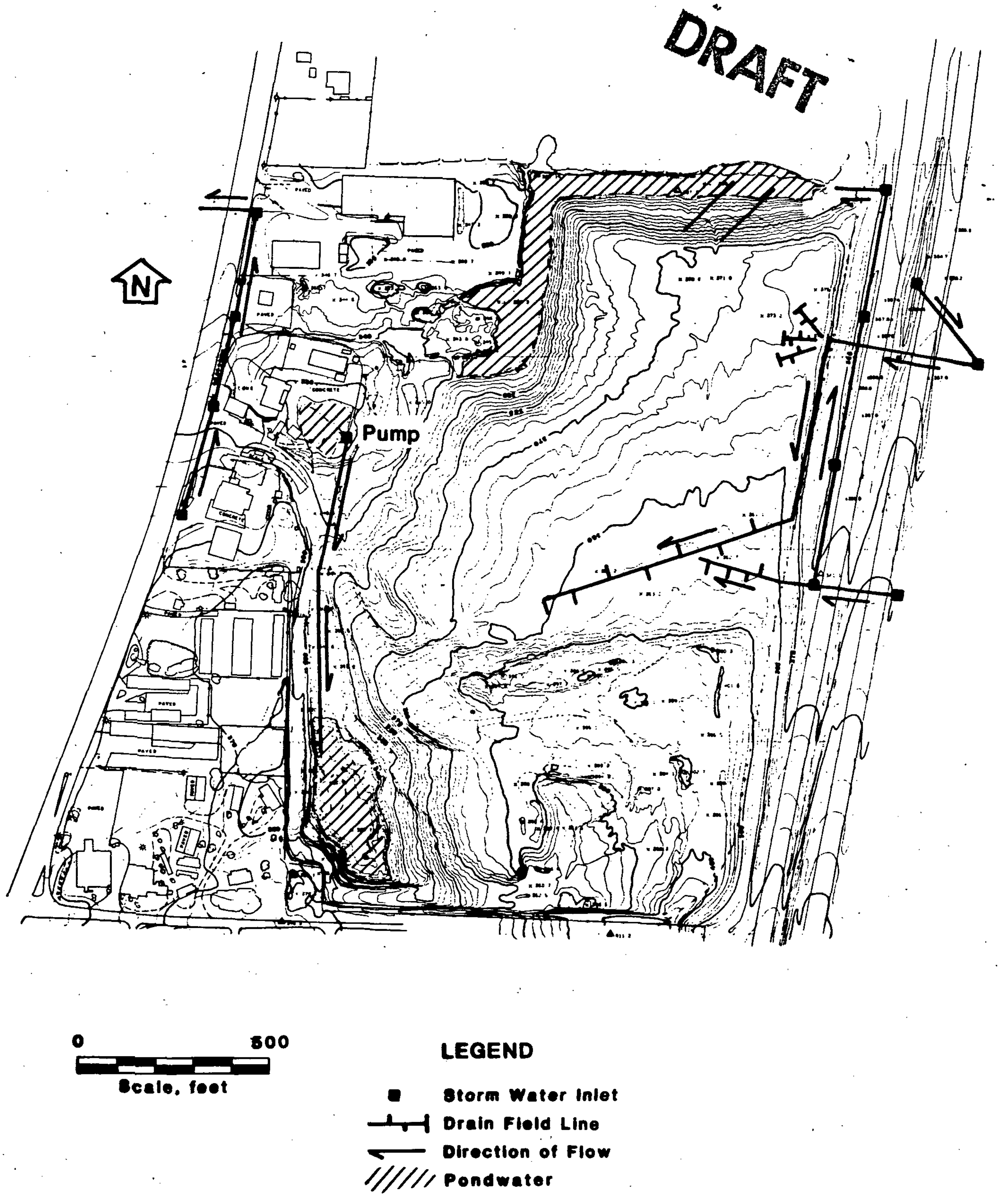
GROUND SURFACE CONTOURS – MIDWAY LANDFILL

Figure 3–3

Golder Associates

APPROXIMATE LOCATION OF EXISTING DRAIN LINES AND SURFACE WATER PONDS

Figure 3-4



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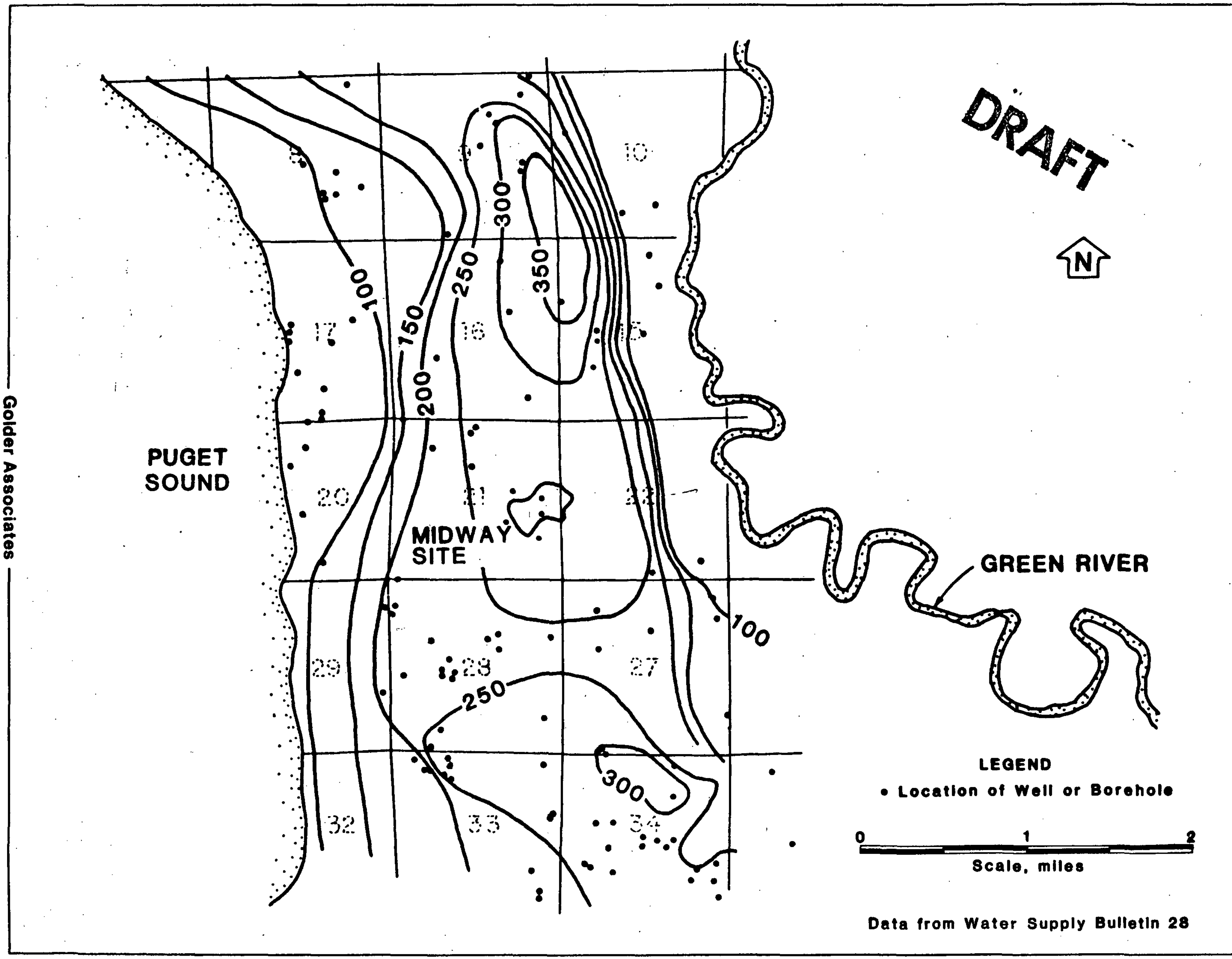
Dwg. No. A 813-1274-018 Date Apr 82 Eng. P.C.



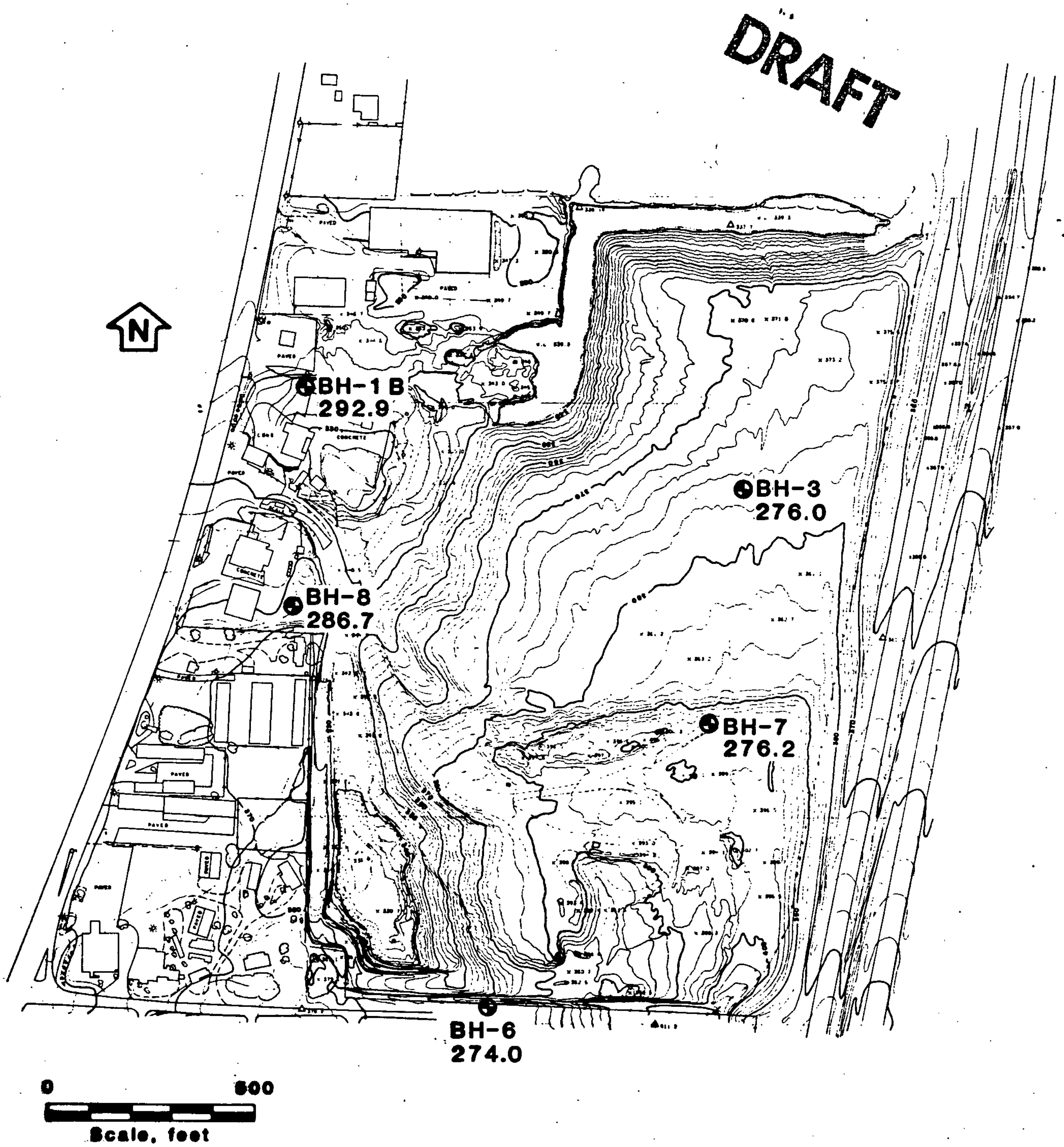
APPROXIMATE REGIONAL WATER LEVEL CONTOURS

Figure 3-5

Golder Associates

GROUNDWATER ELEVATIONS

Figure 3-6



LEGEND

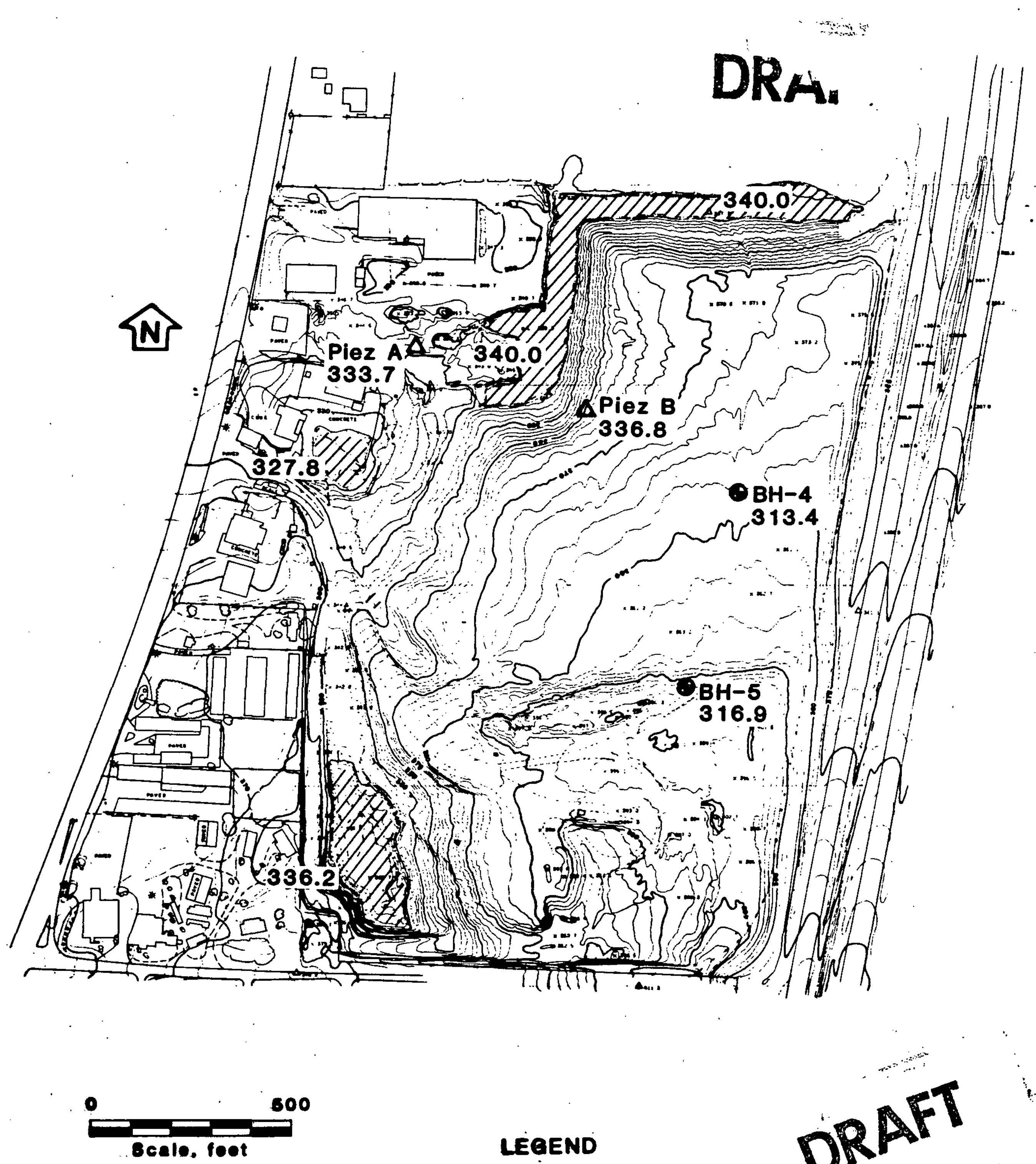
BH-6 Borehole Number

274.0 Groundwater Elevation (feet) Measured 9 March 1982

Rev. ___ Dwg. No. AB13-1276-034 Date Apr 82 Eng. P.C.

WATER ELEVATIONS IN SURFACE PONDS AND WELLS, COMPLETED WITHIN THE LANDFILL MATERIALS

Figure 3-7



LEGEND

BH-4	Borehole Number
Piez A	Piezometer
//////	Surface Pond
313.4	Water Level Elevation (feet) Measured 9 March 1982

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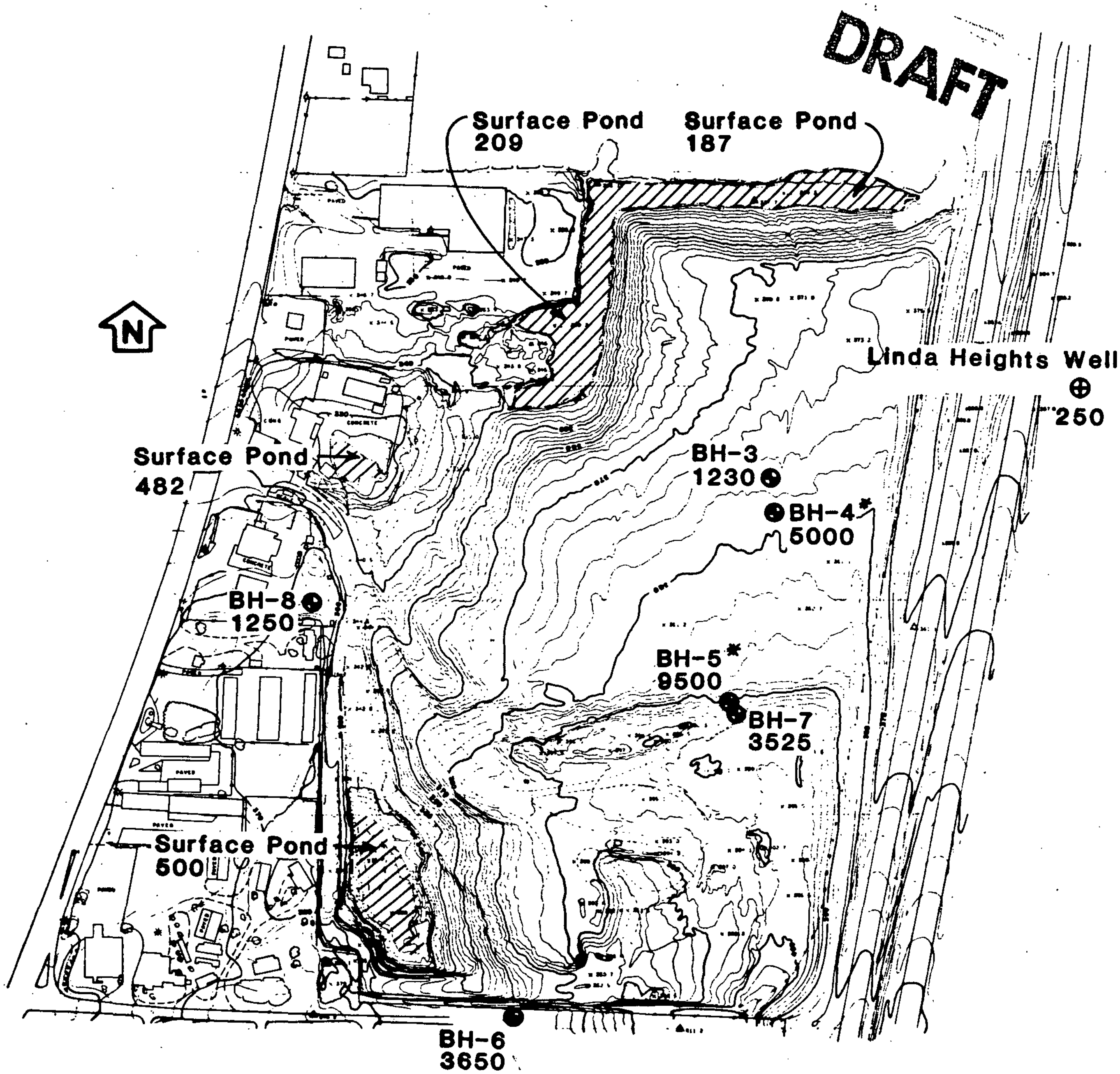
CONDUCTIVITY SURVEY - GROUNDWATER AND SURFACE WATER

Figure 3-8



0 500

Scale, feet

LEGEND

BH-6	Borehole Number
3650	Conductivity in µmho/cm
*	Indicates Well Completed in Landfill
//////	Surface Pond

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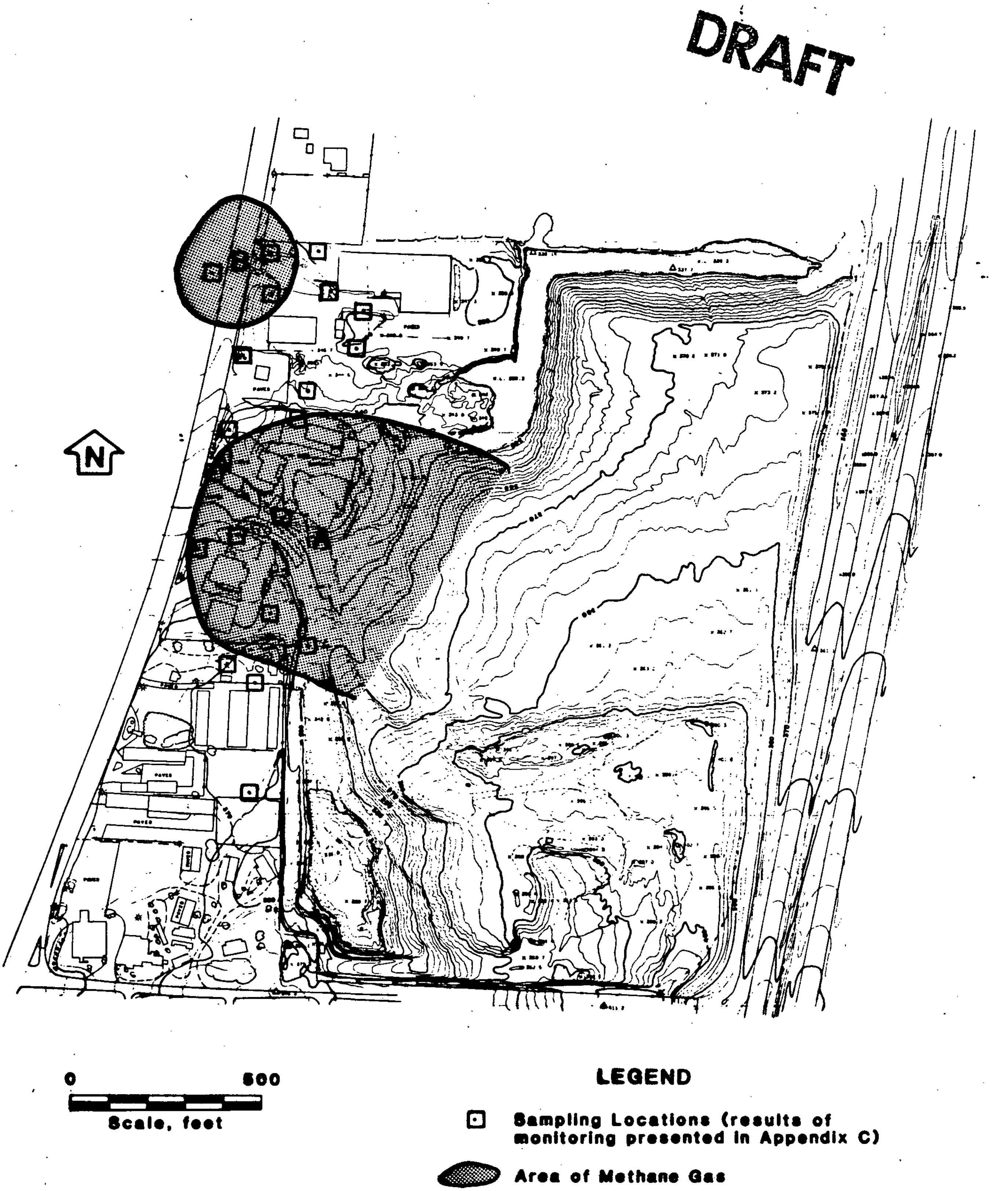
AREAS OF HIGH METHANE GAS CONCENTRATIONS

Figure 3-9



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Dwg. No. A-813-1276-020 Date Apr 82 Eng. P.C.

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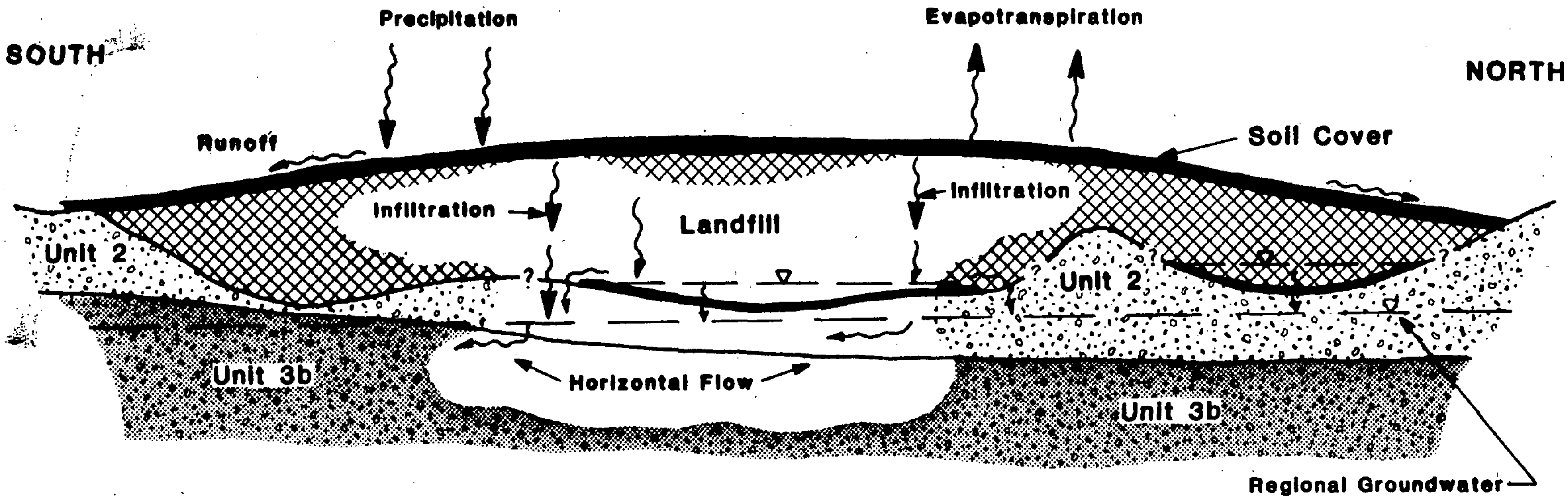

LEGEND

(crosshatch)	Landfill
Unit 2	Gravelly SAND, clayey SAND and GRAVEL, and silty SAND some gravel all with trace to some cobbles and boulders
Unit 3b	GRAVEL, some sand, sandy GRAVEL, and SAND and GRAVEL, all with trace of some silt, cobbles and boulders
(heavy line)	CLAY, SILT and PEAT deposits (extent unknown)

Not to Scale

SCHEMATIC OF POST CLOSURE HYDROLOGIC SYSTEM

Figure 4-1

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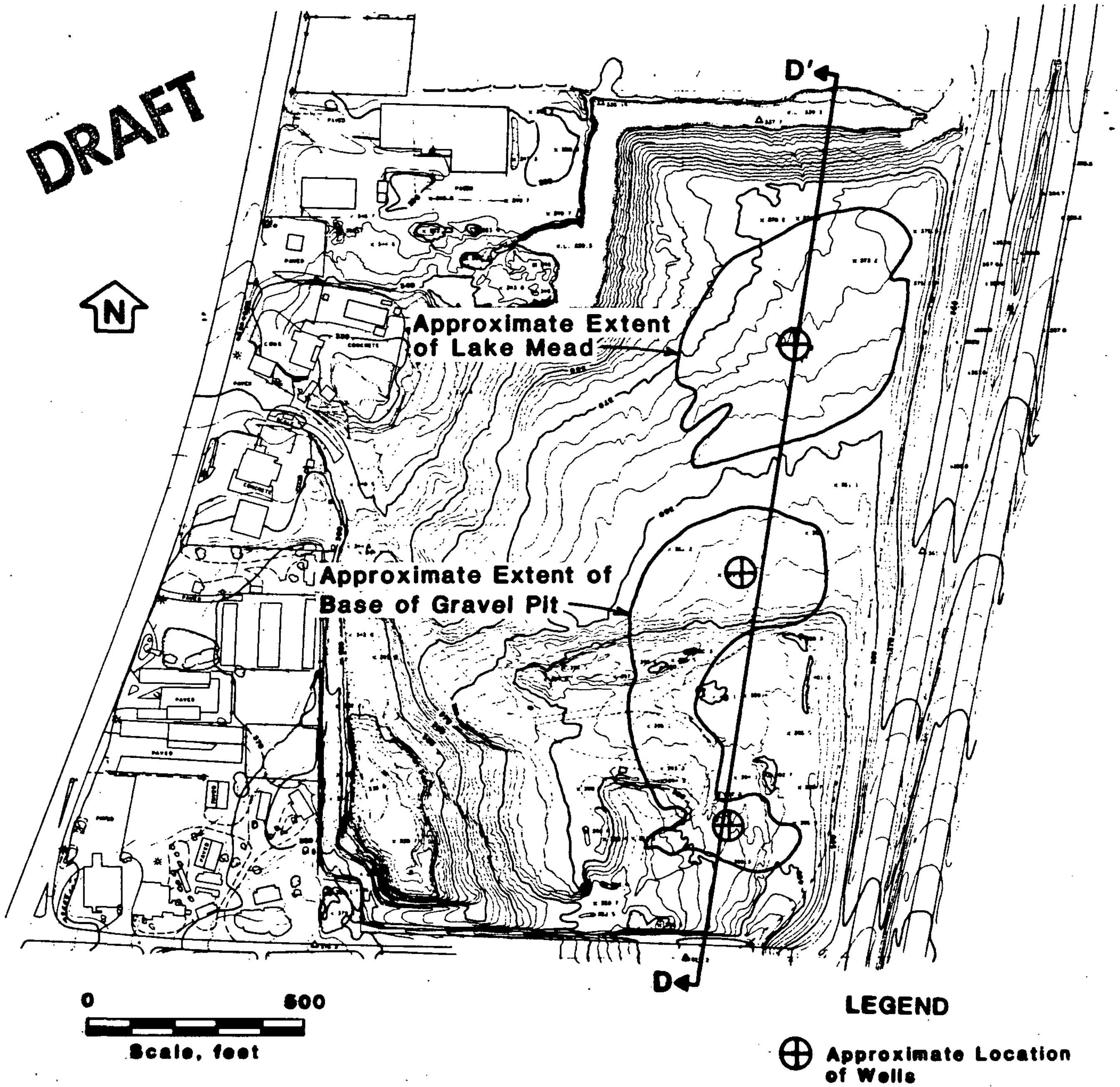
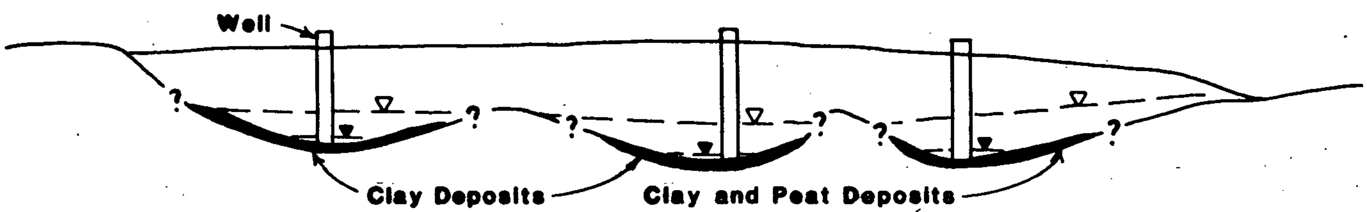
LEACHATE COLLECTION SYSTEM

Figure 4-2



CROSS SECTION D-D'



LEGEND

Not to Scale

Existing Water Levels in Landfill

Proposed Water Levels in Landfill After Pumping

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SCHEMATIC OF SYSTEM FOR GROUND WATER INTERCEPTION

Figure 4-3

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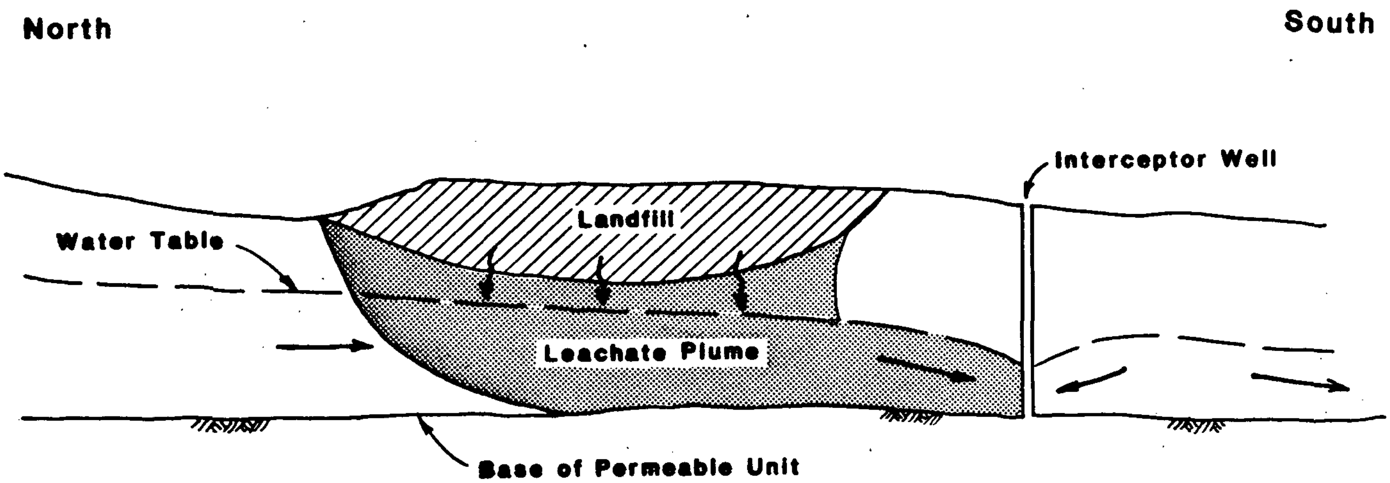

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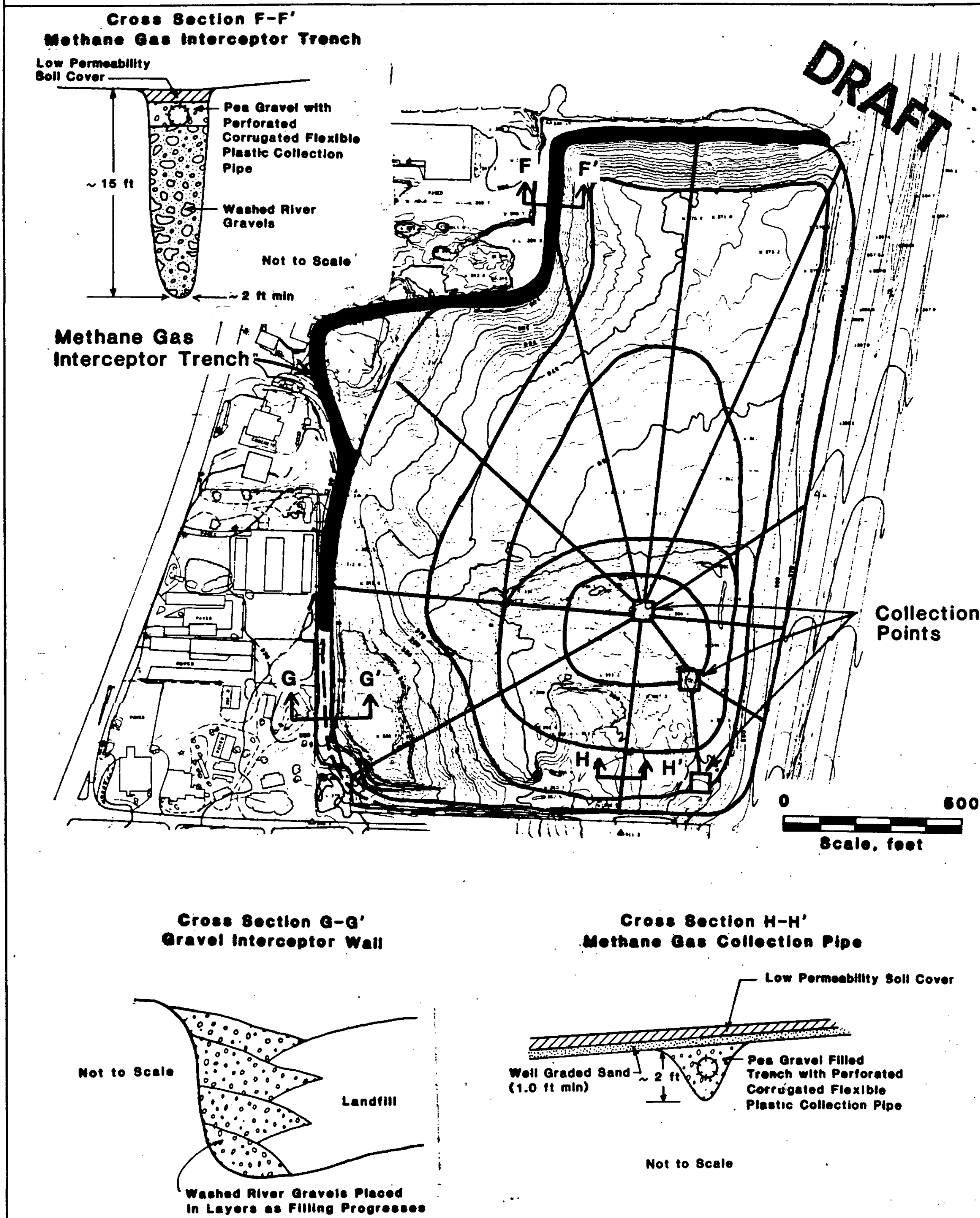
METHANE GAS COLLECTION SYSTEM

Figure 4-4



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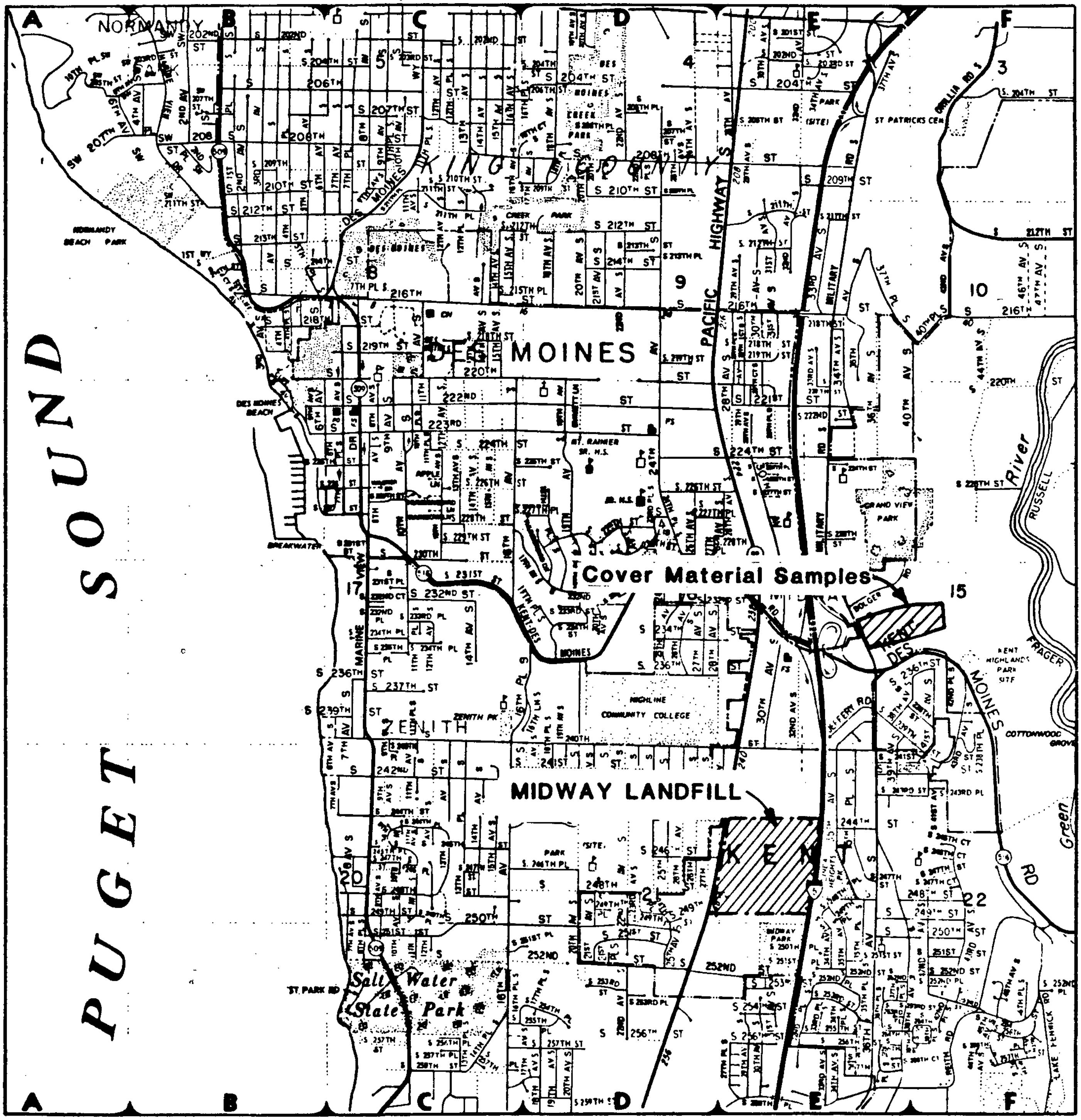
LOCATION OF COVER MATERIAL SAMPLES

Figure 4-5



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Scale, miles

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A813-1276-026 Apr 82 P.C.

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Project Kent-Midway
Golder Associates
Date 4-26-82
By DSM

GRAIN SIZE DISTRIBUTION COVER MATERIAL

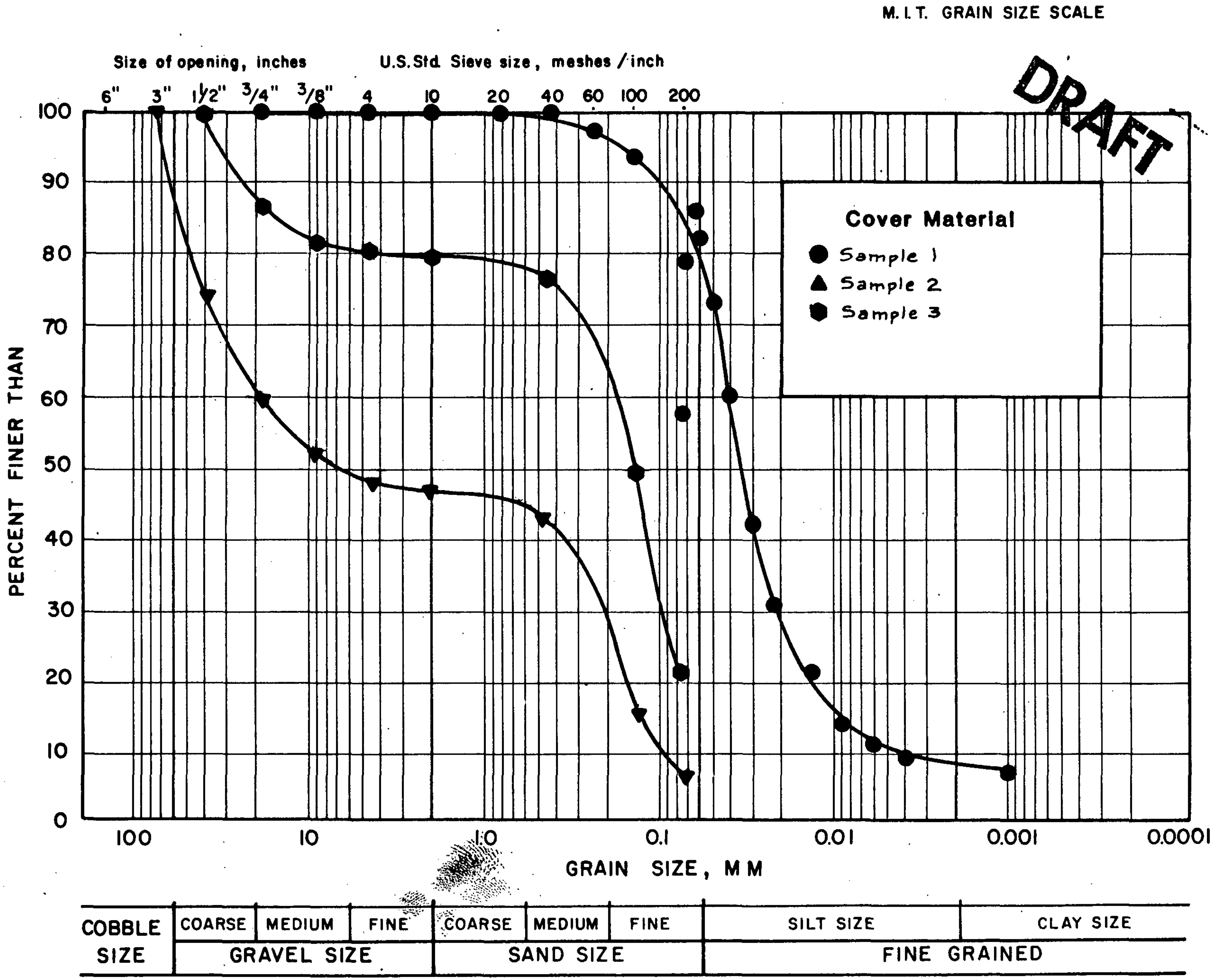
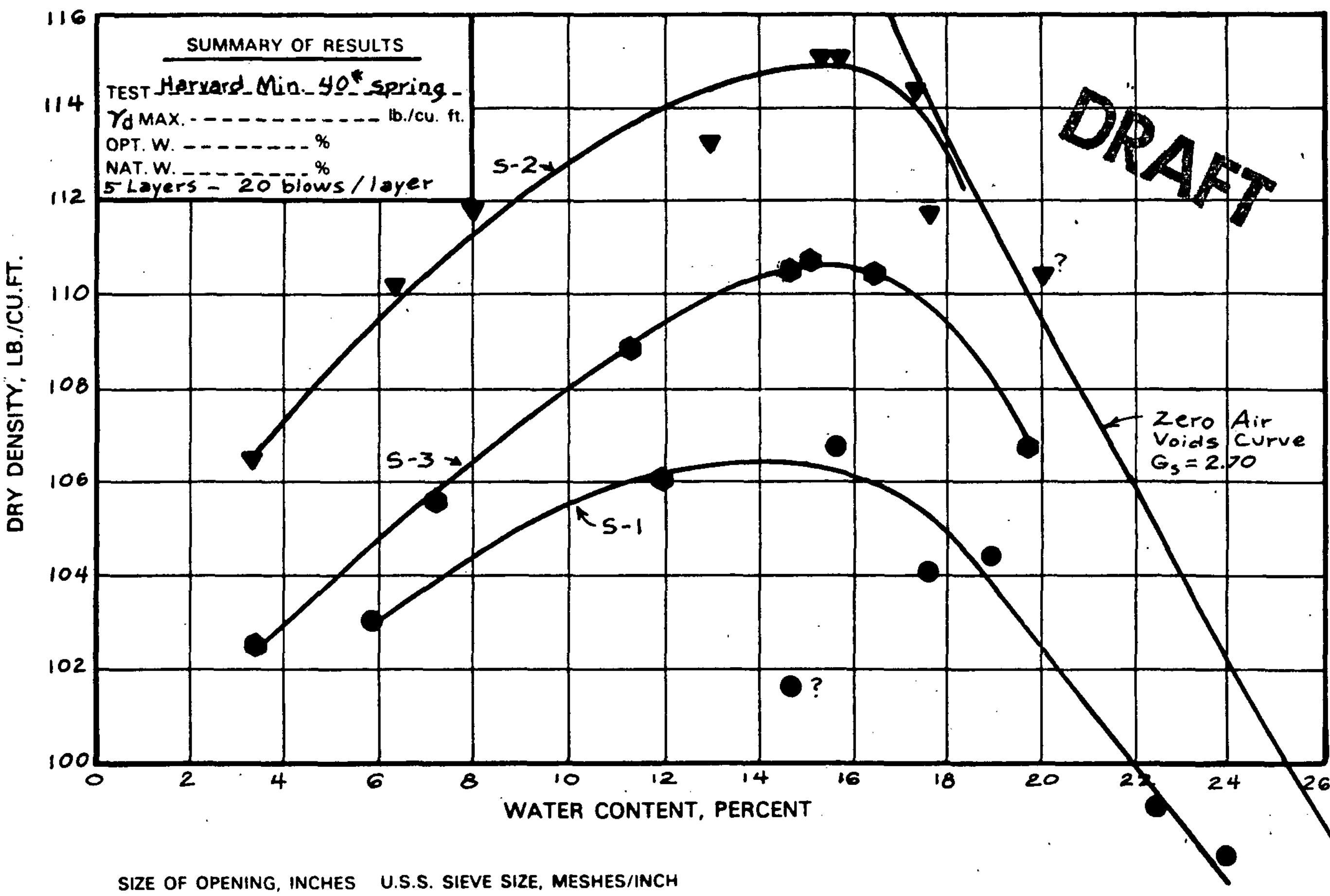
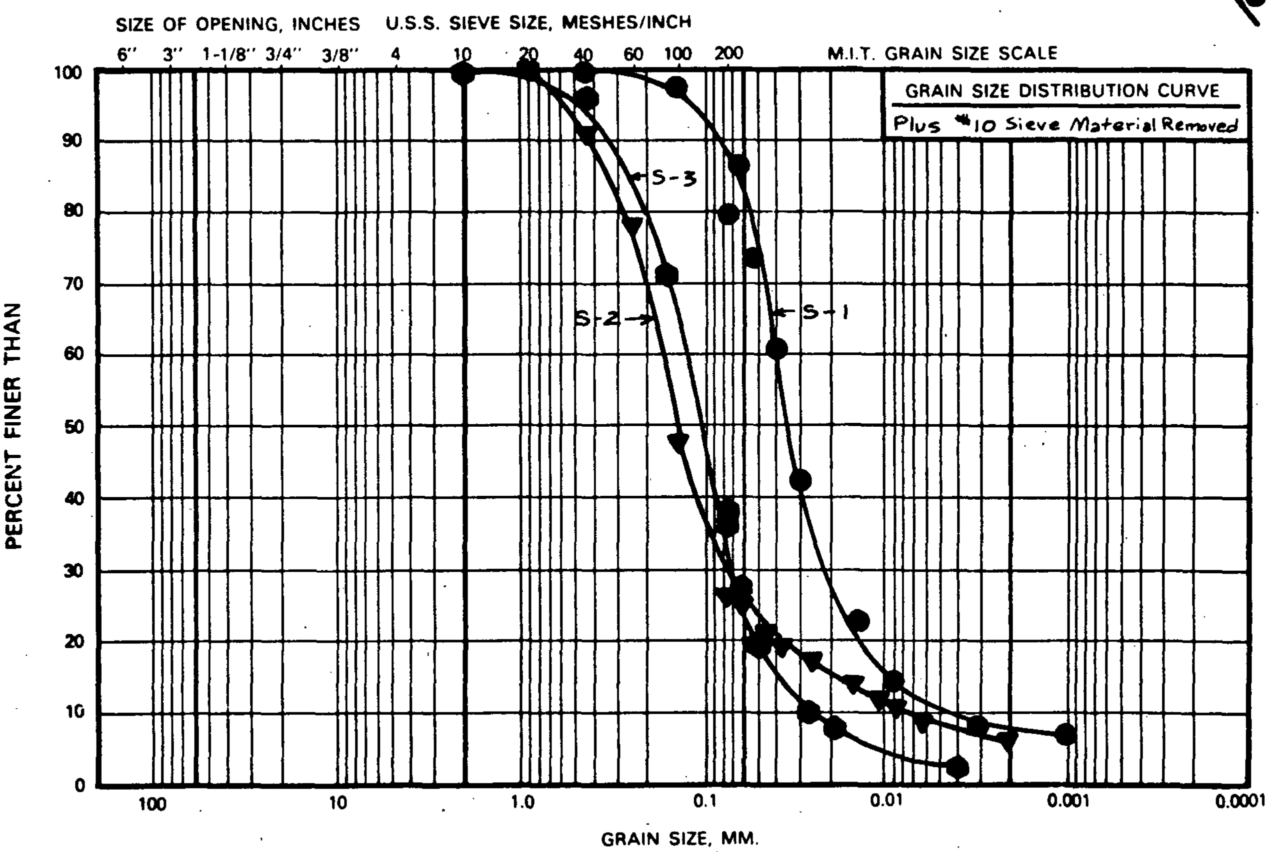


FIGURE 4-6

LABORATORY COMPACTION TEST RESULTS
COVER MATERIAL

FIGURE 4-7





COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

Project No. 813-1276

Project Kent-Midway

Golder Associates

Date 4-7-82

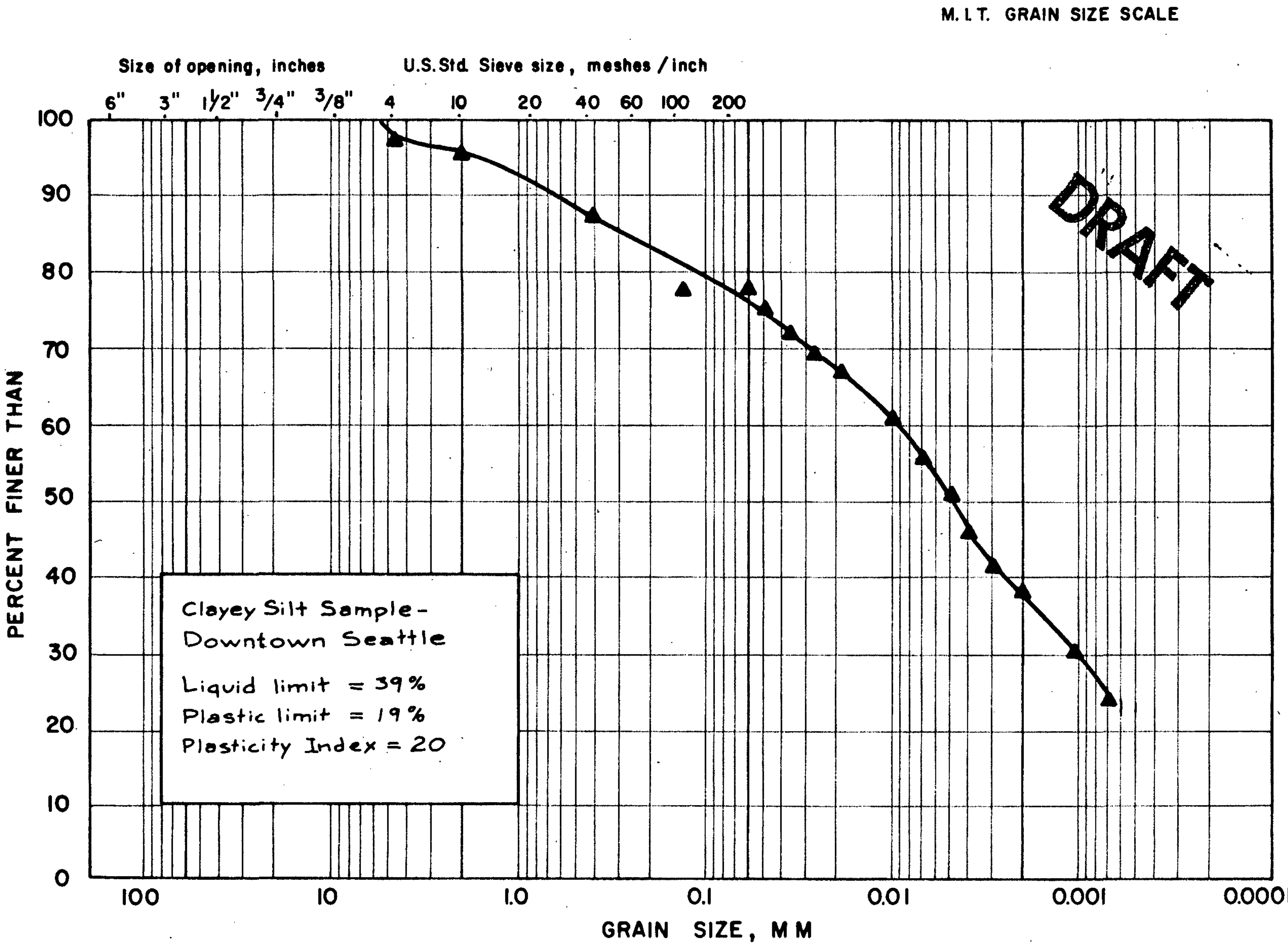
By JTS

A813-1276-027 Apr-82 P.C.

Project No. 813-1276-39
Project Kent Midway

Golder Associates

Date 30 March 82
By JTS



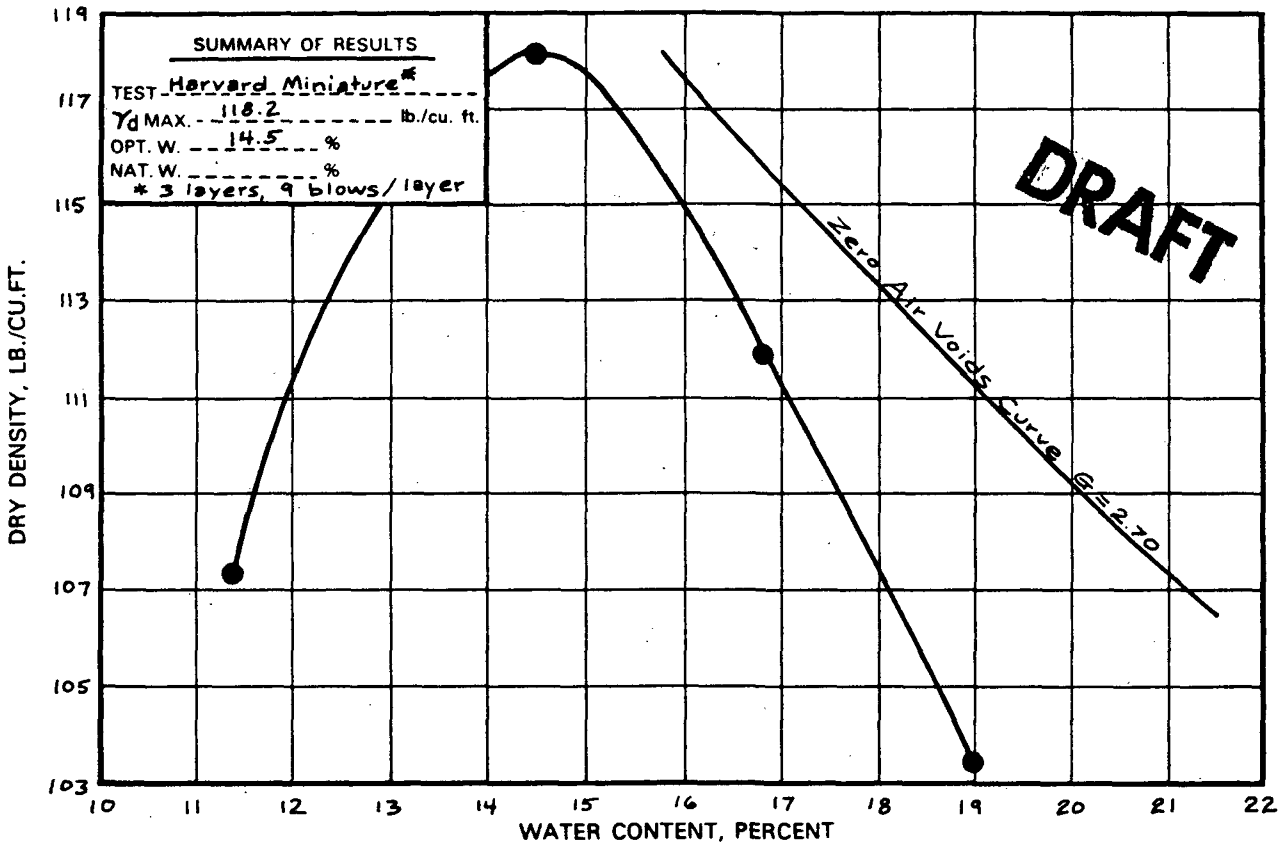
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

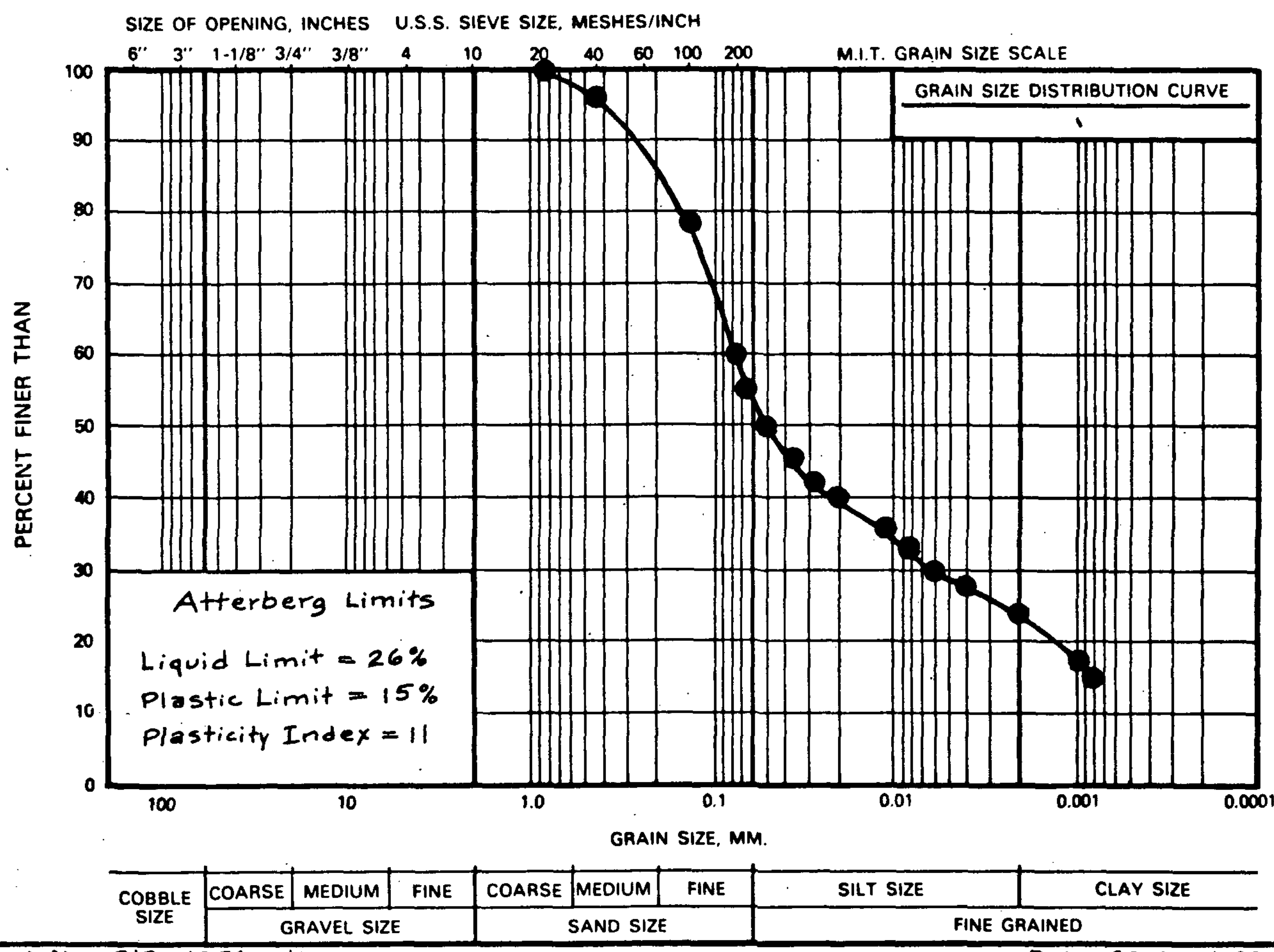
GRAIN SIZE DISTRIBUTION - COVER MATERIAL

FIGURE 4-8

LABORATORY COMPACTION TEST RESULTS –
COVER MATERIAL 60% Sand (S-3): 40% Clayey Silt

FIGURE 4-9





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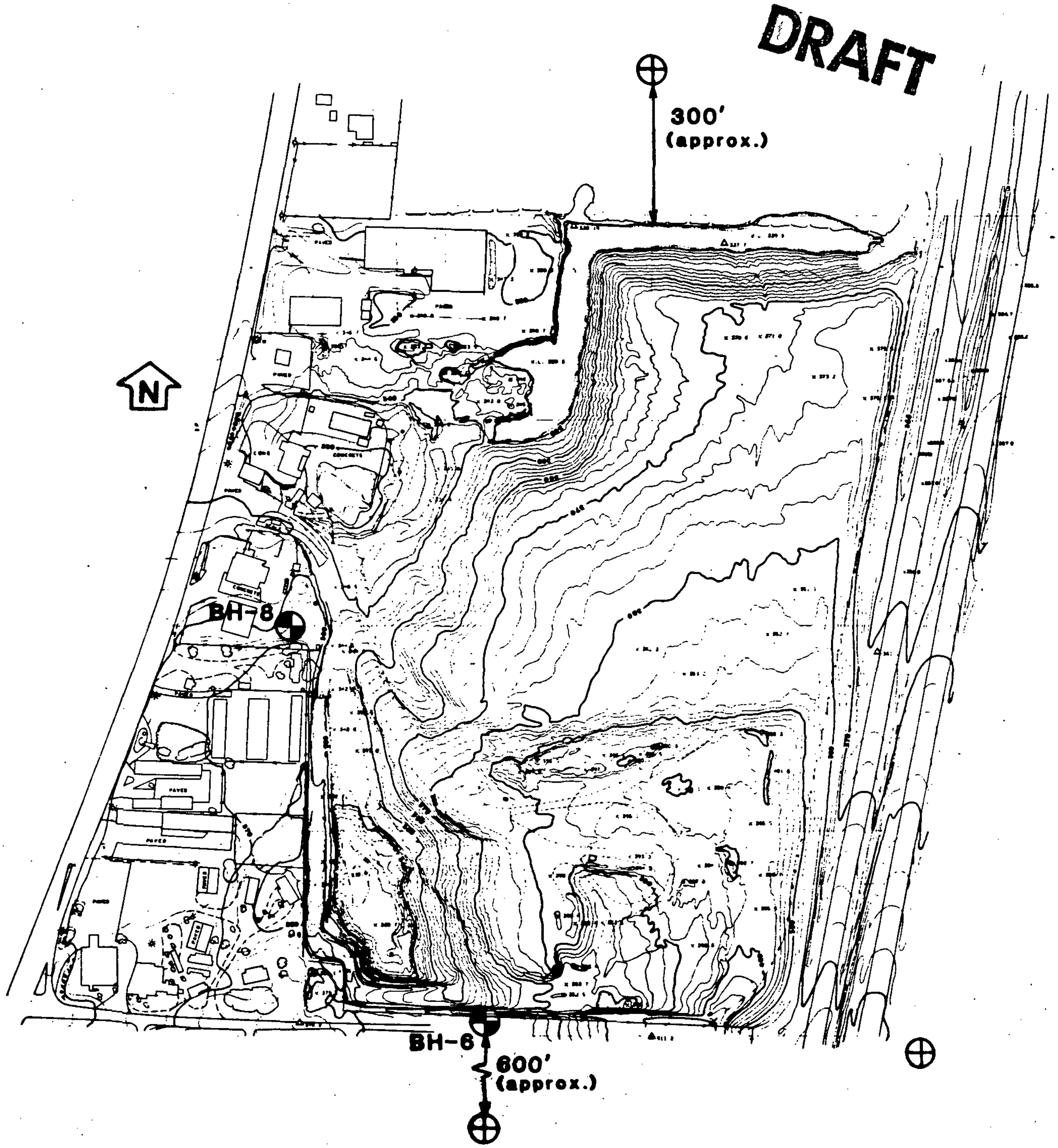
Project Kent Midway

Golder Associates

Date 27 April 82
By BN

PROPOSED GROUNDWATER MONITOR WELL LOCATIONS

Figure 5-1



0 600
Scale, feet

LEGEND

BH-8
Existing Groundwater Sampling Well to Be Used as Monitor Well

Proposed Locations of Additional Monitor Wells

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GROUNDWATER MONITOR WELL INSTALLATION

Figure 5-2

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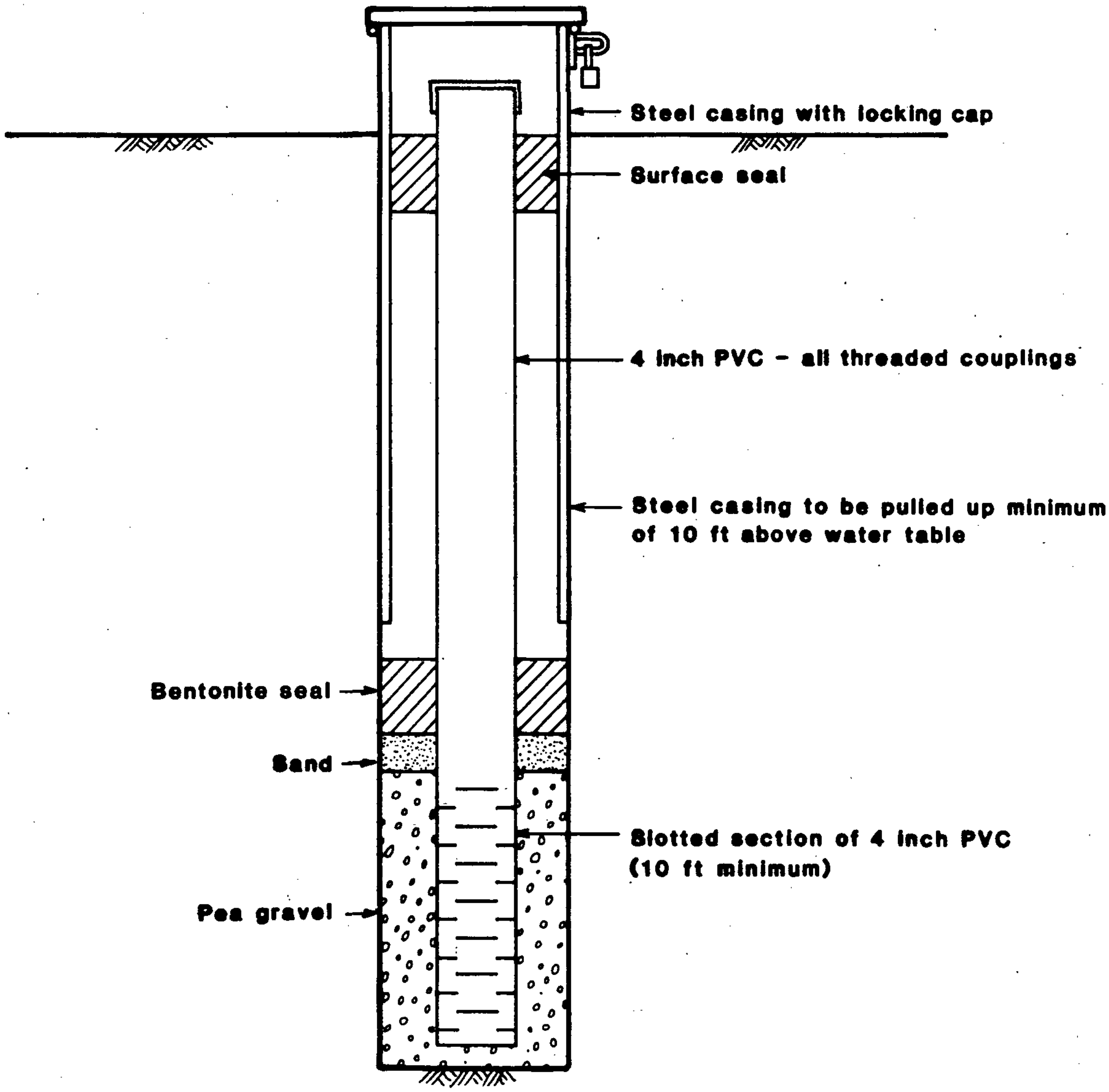

Not to Scale

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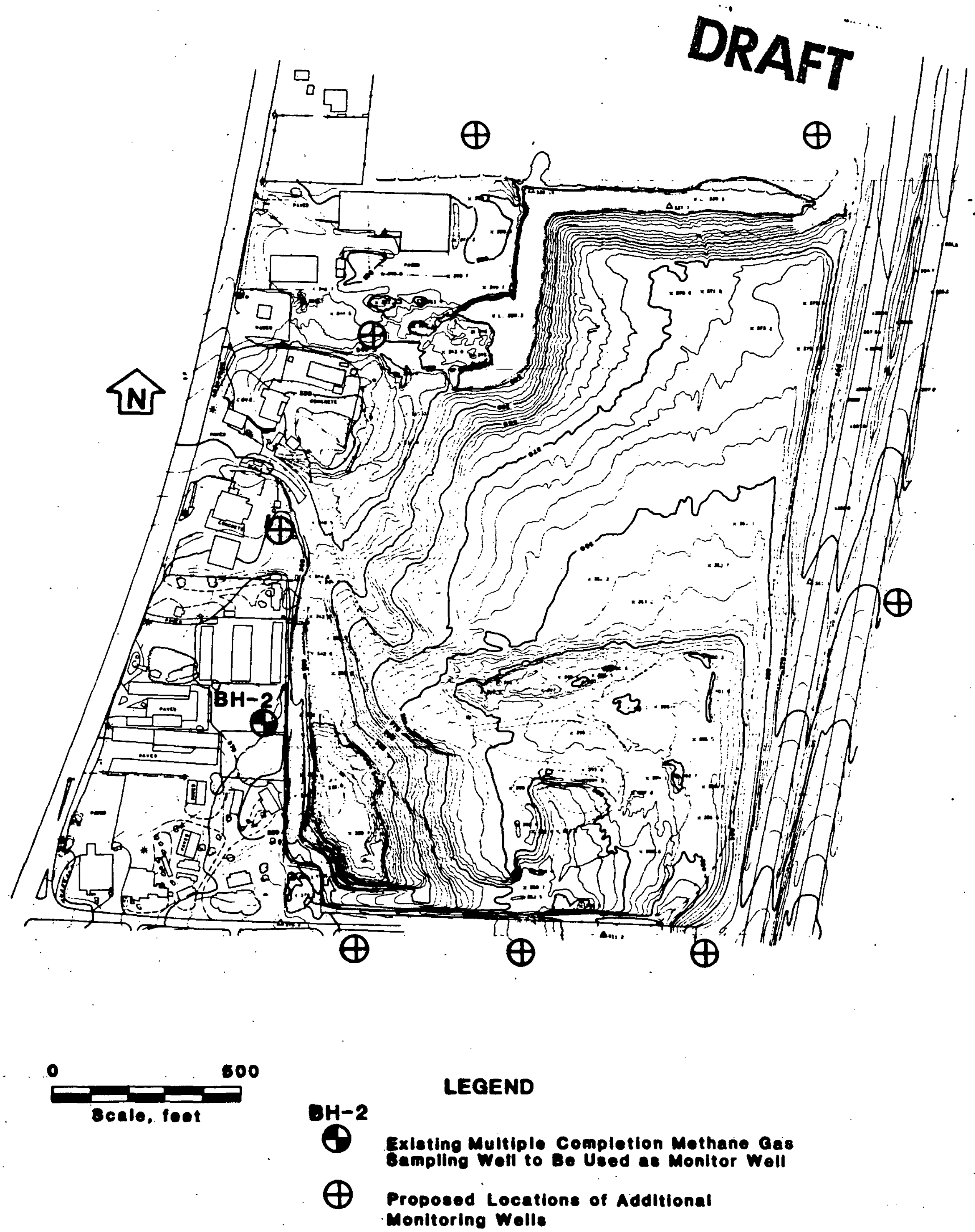
Dwg. No. 817-1276-041 Date June 82 Eng. R.C.

PROPOSED METHANE GAS MONITOR WELL LOCATIONS

Figure 5-3



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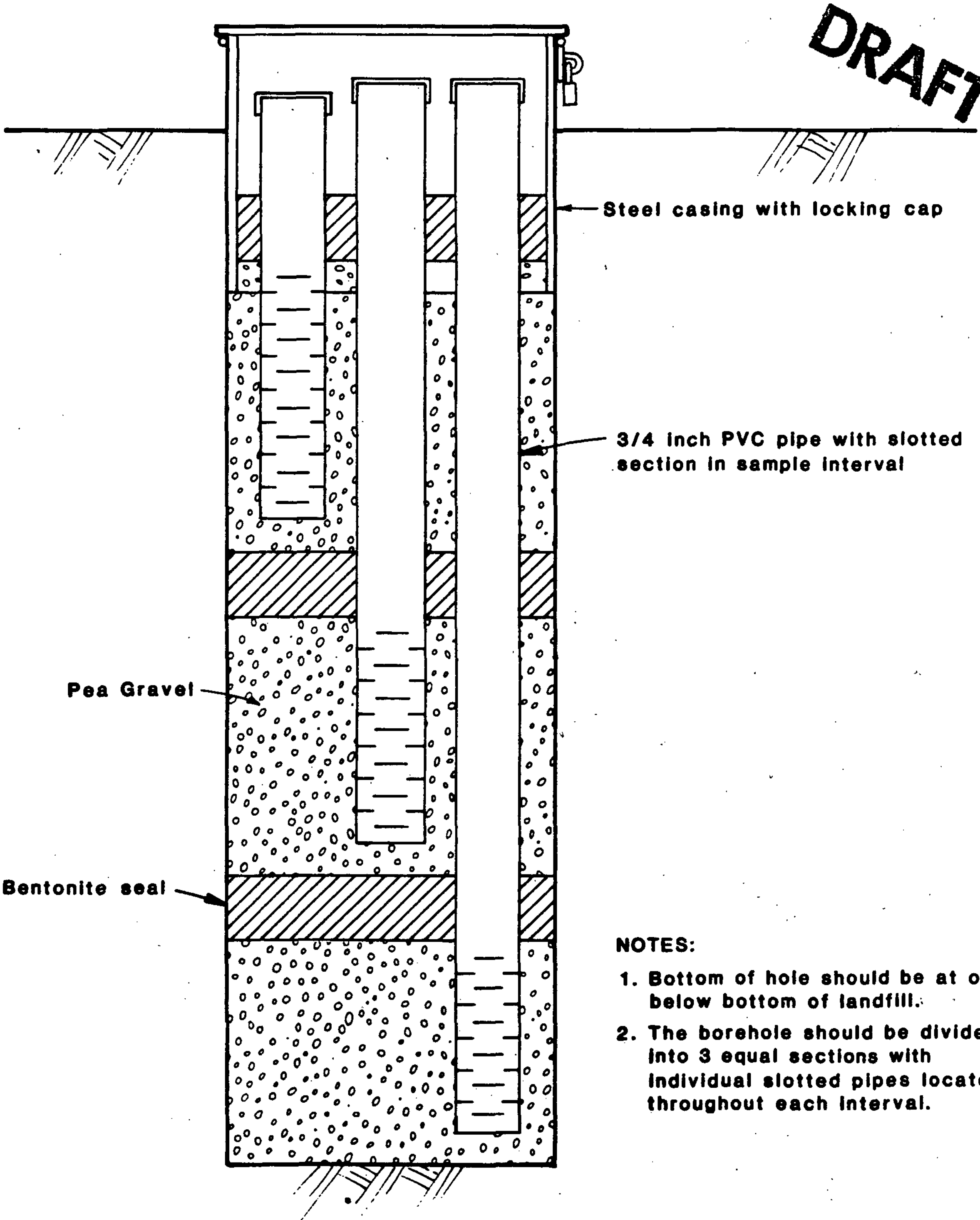
METHANE GAS MONITOR WELL INSTALLATION

Figure 5- 4

DRAFT



NOTES:

1. Bottom of hole should be at or below bottom of landfill.
2. The borehole should be divided into 3 equal sections with individual slotted pipes located throughout each interval.

Typical Gas Well Installation

NOT TO SCALE

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PART II

KENT HIGHLANDS LANDFILL

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
1.1	GENERAL SITE DESCRIPTION	1
1.2	PURPOSE AND SCOPE	2
2.0	INVESTIGATION PROGRAM	4
2.1	REVIEW OF EXISTING DATA	4
2.2	FIELD INVESTIGATIONS	4
2.2.1	Surface Water Mapping	5
2.2.2	Surface and Groundwater Sampling and Testing	5
2.2.3	Methane Gas Monitoring	5
2.2.4	Surveying	6
2.3	COVER MATERIAL SEARCH	6
2.4	LABORATORY INVESTIGATION	6
3.0	GEOLOGIC AND HYDROLOGIC CONDITIONS	7
3.1	GEOLOGY	7
3.1.1	Regional	7
3.1.2	Site Specific	7
3.2	SURFACE WATER	8
3.2.1	Regional	8
3.2.2	Site Specific	9
3.3	GROUNDWATER	9
3.3.1	Regional	9
3.3.2	Site Specific	10
3.4	METHANE GAS	12

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TABLE OF CONTENTS (Cont.)

	Page
4.0 ELEMENTS OF A CONCEPTUAL CLOSURE DESIGN	13
4.1 REGULATORY REQUIREMENTS	13
4.2 SURFACE WATER MANAGEMENT	13
4.3 LEACHATE/GROUNDWATER MANAGEMENT	14
4.3.1 Soil Cover	15
4.3.2 Leachate Production	16
4.3.3 Leachate Collection	16
4.4 METHANE GAS MANAGEMENT	18
4.5 FINAL GRADE CONTOURS	20
4.6 FINAL COVER DESIGN	20
5.0 MONITORING PROGRAM	22
5.1 SURFACE WATER	22
5.2 GROUNDWATER	22
5.2.1 Regulatory Requirements	22
5.2.2 Monitor Well Locations	23
5.2.3 Monitor Well Construction	23
5.2.4 Water Sampling and Analysis	24
5.3 METHANE GAS	26
5.4 SETTLEMENT	27
6.0 CONCLUSIONS AND RECOMMENDATIONS	29
REFERENCES	32

APPENDIX A - DOCUMENTS OBTAINED FOR REVIEW
APPENDIX B - GEOTECHNICAL LOGS
APPENDIX C - FIELD DATA
APPENDIX D - COVER MATERIAL SEARCH
APPENDIX E - HYDROLOGIC ANALYSIS
APPENDIX F - INTERIM GAS INTERCEPTOR TRENCH - MIDWAY

LIST OF TABLES

Table

5-1 Recommended Groundwater Analysis

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LIST OF FIGURES

Figure

1-1	Location Plan - Kent Highlands Landfill
2-1	Location Plan - Boreholes and Test Pits From all Previous Investigations and Cross Section Lines and Surface Water Ponds
3-1	Kent Highlands Landfill Cross Sections A-A', B-B', C-C'
3-2	Ground Surface Contours
3-3	Surface Water Drainage
3-4	Conductivity Survey - Surface Water
3-5	Approximate Regional Water Level Contours
3-6	Groundwater Elevations
3-7	Spring Drains and Leachate Collection System
3-8	Conductivity Survey - Groundwater
4-1	Schematic of Post Closure Hydrologic System
4-2	Proposed Leachate and Spring Drain Monitor Well Locations
4-3	Methane Gas Collection System
5-1	Location of Surface Water Monitoring Points
5-2	Proposed Groundwater Monitor Well Locations
5-3	Groundwater Monitor Well Installation
5-4	Proposed Methane Gas Monitor Well Locations
5-5	Methane Gas Monitor Well Installation

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1.0 INTRODUCTION

1.1 GENERAL SITE DESCRIPTION

The City of Seattle is currently operating a municipal landfill known as the Kent Highlands landfill. The Kent Highlands landfill which has been in operation since July, 1968 is located approximately 16 miles south of downtown Seattle and approximately one-half mile east of the Midway interchange on Interstate 5 (see Figure 1-1). The landfill covers an area of approximately 50 acres and is situated in a small ravine tributary to the Green River.

Previous investigations indicate that the natural ground beneath the landfill was poorly drained and swampy prior to filling. A small stream flowed through the ravine, fed by springs along the foot of the northern slope and by surface runoff.

The entire site has been covered with fill with current operations taking place in the south-central portion of the area. Filling operations on the eastern portion have ceased and the area has been benched with approximately 15 ft terraces, graded to an overall slope angle of approximately 4 horizontal to 1 vertical and revegetated with grass.

The daily operation consists of waste being hauled in trucks from the City of Kent and the City of Seattle. The trucks are unloaded and the waste is then spread by a tractor equipped with special 'sheeps foot" type wheels to increase compaction. Soil from the area immediately north of the ravine is hauled in by scraper and used daily as cover material over the freshly dumped refuse.

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1.2 PURPOSE AND SCOPE

Prior to this study numerous investigations concerning the geological and hydrological conditions at the Kent Highlands landfill had been conducted. The purpose of this investigation was to assemble all available information and ascertain the feasibility of possible closure system elements. Specific objectives were to:

1) Review the geologic and hydrologic conditions beneath and adjacent to the landfill;

2) Analyze the geological and hydrological conditions in order to determine the feasibility of various closure system design elements;

3) Assess the performance of the existing leachate collection system;

4) Address the following elements for a closure system design

   - o surface water management
   - o leachate/groundwater management
   - o methane gas management
   - o cover design;

5) Provide conceptual geotechnical design details for the proposed elements;

6) Recommend a long term performance monitoring system.

This investigation included a review of existing data, field and laboratory investigations of the site and of potential borrow materials, and an engineering analysis of the data to provide designs of various elements of conceptual closure systems.

This study only addresses the geotechnical and hydrological aspects of a closure system. Detailed studies which would be required to assess the extent of potential contamination beyond the immediate landfill area and predict future contaminant migration were beyond the scope of this work, as was the design of measures to mitigate any existing contamination beyond the limits of the landfill.

2.0 INVESTIGATION PROGRAM

2.1 REVIEW OF EXISTING DATA

A comprehensive review of existing information pertaining to the Kent Highlands site was undertaken. Included was:

- previous geologic and hydrologic investigations;
- aerial photographs and topographic maps of the site;
- monitoring records for pneumatic piezometers, slope indicators, and existing wells;
- construction drawings for installation of the toe buttress and the leachate collection system.

A complete list of all documents reviewed is contained in Appendix A. Pertinent data from these documents is discussed in this report.

2.2 FIELD INVESTIGATIONS

Based upon information from previous investigations at Kent Highlands, no further drilling to determine geologic and hydrologic information was deemed necessary. Field investigations were conducted to identify existing facilities, map the occurrence of surface water, obtain field water quality samples, measure water levels, measure methane gas levels, and identify possible sources of final cover material. These items are discussed individually below.

2.2.1 Surface Water Mapping

Surface water occurrence was mapped on January 27, 1982. The locations of seeps and ponded water in and around the landfill were also identified. Water levels of ponds in the proximity of the landfill were later surveyed. Surface water occurrence is shown on Figure 2-1.

2.2.2 Surface and Groundwater Sampling and Testing

Between the dates of January 27, 1982 and April 8, 1982 all piezometers, test wells and monitor wells installed during previous investigations (see Figure 2-1) were located and water level measurements were taken.

Field water quality tests were conducted in all monitor wells using a downhole probe. The water was analyzed for basic field water quality parameters including temperature, salinity and conductivity. A field water quality sample from TW-2 was obtained with a nitrogen sampler and analyzed. Basic field water quality tests were also conducted in surface water ponds present at the time of the field study.

The results of all field water quality tests are listed in Appendix C. No laboratory water quality analyses have been completed to date.

2.2.3 Methane Gas Monitoring

The presence of methane gas was tested for in all piezometers, test wells, and monitor wells that were accessible. Results are presented in Appendix C.

2.2.4 Surveying

The City of Seattle provided services to survey the locations and elevations of all piezometers, test wells, monitor wells, and surface water ponds at the Kent Highlands site. Results are presented in Appendix C.

2.3 COVER MATERIAL SEARCH

An investigation was undertaken to determine potential sources of fine sand, silt or clay which could be used separately or combined with other granular materials to form a suitable final cover. A number of City, County and State offices were contacted concerning possible sources of final cover materials. A complete list of the people and offices that were contacted as well as any information that was obtained is presented in Appendix D.

2.4 LABORATORY INVESTIGATION

A laboratory investigation was conducted to ascertain the basic geotechnical and hydrologic properties of the potential cover materials.

Laboratory tests conducted included the following:

- gradation
- compaction
- natural moisture content
- permeability

Procedures for individual tests are identical to those described in Part I of this report. The results of the laboratory investigation, are presented in Section 3.0.

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3.0 GEOLOGIC AND HYDROLOGIC CONDITIONS

3.1 GEOLOGY

3.1.1 Regional

The geographic features in southwestern King County are a result of the Vashon glaciation. The steep sloped ravine, in which the Kent Highlands landfill is located, is a stream erosion feature cut into the bluffs along the west side of the Green River Valley. The lower portions of these bluffs consist of kame terrace deposits of silty sands and gravels which were deposited alongside earlier formations. West of the kame terrace deposit, the surface is covered by a ground moraine underlain by glacial drift deposits consisting generally of dense silty sand with varying amounts of gravel.

3.1.2 Site Specific

The site specific geologic conditions in the vicinity of the Kent Highlands landfill were determined from review of previous investigations of the site.

Generally, in the upper portions of the ravine the stratigraphy consists of landfill materials overlying glacial drift deposits of fine to medium silty sand to sandy gravel. Underneath these glacial deposits are stream and/or lake deposits which consist of clay and silt to fine sand. Underlying the majority of the landfill is clayey silt with fine sand seams and gravelly clay and silt. Exposed in the upper portion of the ravine along the south wall is a hard stratified silt. In the ravine bottom are recent deposits of loose sand containing organic matter. At the mouth of the ravine a deposit of peat, containing lenses of sand, blankets the bottom to a depth of approximately sixteen feet.

Figure 3-1 shows three cross sections through the landfill. These sections have been drawn to intersect several of the exploration locations and generally indicate the major geologic features occurring at the landfill.

To insure the stability of the eastern slope of the landfill a rockfilled toe buttress was constructed to increase the shearing resistance at the toe and provide drainage of groundwater/ leachate out of the landfill.

Piezometers were placed in the peat deposit located in the lower portion of the ravine to monitor the consolidation of the peat as the filling operation proceeded. Slope indicator casing was installed at two points down-slope of the toe buttress to monitor any slope movements which would indicate the initiation of any slope instability.

Data from these installations has been reviewed. Piezometers have not shown any excessive pore pressure build up in the peat deposits although a gradual rise in the piezometric levels has occurred which is believed to be a result of increased leachate levels within the landfill. Monitoring of slope indicator casing has not indicated any displacement since installation.

3.2 SURFACE WATER

3.2.1 Regional

Figure 3-2 shows the ground surface contours in the vicinity of the Kent Highlands landfill. The dashed line indicates the approximate drainage divide between the Green River and Puget Sound. Surface water falling on the Kent Highlands site will flow into the Green River.

3.2.2 Site Specific

Figure 3-3 illustrates existing surface water facilities at Kent Highlands. Offsite surface water originating west of the landfill is collected in a storm drainage line that routes water around the south side of the landfill to a settling pond in the valley floor adjacent to the Green River. Offsite surface water from north of the site is collected in onsite settlement ponds and eventually discharges into the Green River. Onsite surface water is conducted through various lined and unlined channels into one of three settlement ponds. From the settlement ponds it is also discharged into the Green River.

Field water quality tests were conducted in the surface water settlement ponds, the un-named creek and the Green River. The results of all field conductivity tests are shown in Figure 3-4. Conductivity readings for uncontaminated surface water in this area are probably in the range of 100 to 300 μ mhos/cm, with readings greater than this indicating leachate contamination.

As can be seen in Figure 3-4, leachate contamination has been noted in the surface water ponds and drainage courses east of the toe buttress. According to city officials, this contamination is thought to be a result of leachate migration prior to the construction of the toe buttress and settlement ponds. Leachate seeps near the surface of the landfill also probaly contribute to the contamination of surface water draining off of the site.

3.3 GROUNDWATER

3.3.1 Regional

Approximate contours of the regional groundwater table are shown in Figure 3-5. These contours were constructed from static water

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levels of various wells in the area reported in Water Supply Bulletin No. 28 (Luzier, 1969). Water levels were obtained from drillers logs and were measured over a period of years from various depths and aquifer horizons resulting in significant scatter in the readings. Non-representative readings may also have resulted from water level measurements taken shortly after wells were pumped which could account for some of the areas of localized depression of the groundwater contours. In general, the groundwater contours follow the same pattern as the ground surface contours. Regional groundwater contours indicate that there is a groundwater mound north of the Kent Highlands landfill from which water is flowing out in all directions. The landfill is located on the east side of this mound and groundwater is flowing east through the site towards the Green River.

3.3.2 Site Specific

Static water level elevations in all piezometers, well points and monitor wells that were located during the field investigation were measured and are shown in Figure 3-6. Some piezometers and wells installed during previous studies were either not accessible or no longer exist. Water levels indicate that groundwater is flowing into the ravine and then towards the Green River.

During operation of the landfill various facilities were constructed to control groundwater and leachate. These facilities are schematically shown in Figure 3-7. Investigations conducted prior to filling identified a zone of groundwater springs on the north side of the ravine near elevation 100 feet. These springs are currently being intercepted by a system of drains and conducted in CMP culvert to a leachate treatment pond. Groundwater/leachate within the landfill material is being collected by various leachate collection lines, generally constructed of 4 inch corrugated ABS plastic drain pipe, located within the landfill. These lines are not indicated on Figure 3-7 because their location and condition are not known. Additional lines are placed during the filling operation to intercept and collect leachate seeps once they appear at the surface.

The toe buttress drain collects groundwater/leachate which is pumped into the leachate treatment pond. Currently a small pond located just below the toe drain is collecting surface water flowing off the landfill which contains leachate. There is some indication that small quantities of leachate may be bypassing the toe drain and also entering this small pond. These seeps are apparently surficial and do not indicate leachate flow in groundwater bypassing the toe drain. Water collected in this pond is also being pumped into the leachate treatment pond. All water after primary treatment in the leachate treatment pond, is discharged into Metro sewer lines.

Field water quality tests were conducted in all monitor wells located below the toe drain and on a sample obtained from TW-2 located north of the fill. The results are presented in Appendix B and conductivity values are shown in Figure 3-8. Conductivity readings for uncontaminated groundwater in this area are in the range of 100 to 200 μmhos/cm based upon samples from TW-2 and the deep monitor wells. Readings over this indicate possible leachate contamination.

Monitor wells which are located downstream of the toe drain are constructed of 2-inch diameter PVC pipe with a 2-foot slotted tip. Each monitor well consisted of 3 pipes sealed into specific intervals with bentonite. Results indicate that leachate has only contaminated the near surface soils. This contamination probably occurred before the toe drain and buttress were

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installed. The landfill had been in operation approximately 11 years before these installations were completed. Water levels in the monitor wells indicate that there is a positive gradient towards the toe drain from east of the buttress (see Figure 3-1). The toe drains thus provide a sink for the groundwater and leachate in the area and should prevent migration of leachate outside of the landfill along the eastern boundary.

3.4 METHANE GAS

The presence of methane gas was tested for in all piezometers, test wells and monitor wells that were accessible at the time of the field investigation. The presence of methane was detected in PZ-2 (shallow) and PZ-5 which had concentrations of 50% and 0.8%, respectively. All remaining sites indicated less than 0.1%. Gas migration is probably occurring in the medium to coarse-grained glacial drift deposits that are in contact with the landfill materials (see Figure 3-1).

Various gas burners are located throughout the landfill to vent methane gas. In most cases they have been placed over leachate collection lines which also serve as methane collection lines. The burners generally consist of metal pipe approximately 10 feet long with a wind shield at the top. Based on observations, there appears to be a fairly steady flow of gas from these burners.

4.0 ELEMENTS OF A CONCEPTUAL CLOSURE DESIGN

4.1 REGULATORY REQUIREMENTS

The specific regulatory requirements pertaining to the Kent Highlands landfill are the same as those for the Midway landfill presented in Part I of this report.

The King County Health Department and the Washington Department of Ecology have enforcement power over the regulations. The various conceptual closure design elements and recommendations discussed below are intended to satisfy regulatory requirements concerning:

- Surface water management
- Leachate/groundwater management
- Methane gas management
- Final grade contours.

The particular elements that are incorporated into the final closure system at the Kent Highlands landfill will depend on a number of factors including regulatory requirements, final land use and cost.

4.2 SURFACE WATER MANAGEMENT

Offsite surface water runoff is currently being conducted around the site and into settlement ponds before it is discharged into the Green River. Onsite surface water is also being conducted into settlement ponds before discharging into the Green River. The initial conductivity measurement of the surface water indicates that it is probably being contaminated with leachate. Contamination is probably the result of leachate seeps on the surface of the landfill and surface runoff from areas of exposed refuse. After closure and placement of a final cover this contamination should not be a continuing problem provided the integrity of the cover is maintained.

As part of the final closure plan, an effective surface water management system must be developed which provides adequate drainage and release of surface water and controls infiltration into the landfill. This will probably involve appropriate grading of the site to provide drainage and analyses to determine if existing retention facilities are adequate to handle the design storm runoff. Specific recommendations for surface water management will be presented in the final closure plan.

The major geotechnical concern regarding surface water management is the control of infiltration into the landfill since this serves to generate leachate. Measures to control infiltration include contour grading of the site and placement of a soil cover. Details of these measures are discussed further in Section 4.4 and 4.5 respectively.

4.3 LEACHATE/GROUNDWATER MANAGEMENT

A leachate collection system is currently in operation at the Kent Highlands landfill consisting of the toe buttress drains, the spring drains and other leachate drains located beneath and in the fill. It is apparently intercepting most or all leachate which is being produced by the landfill. Field water quality tests and water level elevations indicate that the spring drains are operating effectively in intercepting the spring water identified along the north side of the ravine. Due to poorly sealed joints or deterioration of the CMP line carrying the spring water, a small amount of leachate appears to be contaminating the water at some point along the line.

If the leachate collection system continues to operate in its current condition the major source of leachate after steady-state post-closure conditions have been reached will be surface water infiltrating through the cover. Various conceptual designs for the control of surface water infiltration and for insuring the long term performance of the existing leachate collection system are presented below.

4.3.1 Soil Cover

Placement of a cover is intended to restrict the quantity of surface water infiltrating into the landfill and thus reduce leachate production. As a minimum requirement, the landfill should be capped with 2 feet of compacted soil or equivalent. Generally, soil covers should consist of a relatively low permeability compacted soil layer overlain by topsoil and a vegetative cover. At the Kent Highland landfill, however, due to the existence of a leachate collection system, a low permeability cover may not be required. Placement of a permeable soil cover would result in greater long-term leachate production but if appropriate measures were taken to collect and treat the additional leachate, this may be a more attractive option than placement of a low permeability cover. The long-term leachate production with a permeable soil cover would probably be similar in volume to that currently being produced. In either case, the cover should be embedded at least 2 feet into the natural soils surrounding the landfill. In general, soils for a final cover should be chosen which retard infiltration, are resistant to wind and surface water erosion, are plastic enough to accommodate settlements with limited maintenance and are fertile enough to sustain vegetation. The specific design of a soil cover and availability of materials are addressed in Section 4.5.

4.3.2 Leachate Production

A compacted soil cover will not provide a completely impermeable barrier to infiltration. Therefore, an estimate of infiltration through the cover into the landfill has been made to assess potential quantities of leachate production for various cover permeabilities.

The hydrologic system existing after placement of a soil cover is conceptually shown in Figure 4-1. Water is provided to the landfill by precipitation and is lost by surface runoff, evapotranspiration and infiltration through the landfill into the groundwater. Water within the landfill will flow vertically until encountering low permeability layers within the fill itself or until it reaches the regional groundwater.

A water balance method was used to estimate infiltration, the details of which are provided in Appendix E. For the anticipated range of cover permeabilities, 10^{-5} to 10^{-7} cm/sec, the volume of annual infiltration through the cover ranges from approximately 28.75 to 1.3 acre-feet.

The above quantities of leachate production are only estimates. Variations in cover characteristics, vegetation, precipitation and other factors will significantly affect the net quantity of leachate produced in the landfill.

4.3.3 Leachate Collection

The existing leachate collection system is considered to be adequate to control leachate produced in the landfill provided that the existing spring drains and leachate collection lines remain operational. It is our understanding that the spring

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drain lines are constructed of 12-inch diameter CMP. The corrosive environment within the landfill will almost certainly cause the metal pipe to deteriorate. Field water quality tests indicate that at present a small amount of leachate may already be entering this pipe. Plugging or complete collapse of the spring drain line will increase seepage into the landfill thus producing more leachate. If the permeability of the landfill is low enough, a localized groundwater mound could form within the landfill material which might result in leachate flowing northeastward, bypassing the leachate collection system.

At this time it is not known whether the spring drains must remain functioning after closure to prevent leachate from bypassing the leachate collection system. One method of keeping them functional is to replace the existing spring drain line with a corrosive resistant line. This would require excavating through the fill to remove the old pipe and then replacing it with a thickwalled polyethelene pipe. During construction the spring drains would also be inspected to determine their condition. Based on the length and depth of the line, a large portion of the landfill materials would have to be excavated for the installation. Thus, it is not considered to be a practical or an economically attractive alternative.

An alternative to replacing the existing line is to provide a groundwater monitoring system capable of detecting leachate buildup in the area which could cause bypassing of the collection system. If required, water could be pumped from wells located in fill adjacent to the spring drains thus preventing any leachate escape. As with the water collected from the spring drains, water pumped from these wells would have to be treated before being discharged. Figure 4-2 shows approximate locations of these monitoring wells.

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Previous studies (Johnson and Kokita, 1976) have shown that intercepting these springs with pumped wells, before they enter the landfill, is not a practical alternative. An excessive number of wells and high pumping rates would be required to intercept the spring completely and it may result in leachate being drawn into the well due to the induced gradients towards the well.

4.4 METHANE GAS MANAGEMENT

The majority of methane gas generated by the landfill is venting to the atmosphere or being burned by gas burners located in the landfill. Some methane gas has been detected to be traveling to the west of the landfill within the glacial deposits that are in contact with the landfill. The methane gas management system must address both types of migration.

For the control of deep methane gas migration west of the landfill, a series of deep methane gas collection wells could be constructed within the permeable deposits in which the gas is migrating. The number and spacing of the wells would be dependent on further exploration and testing to determine the concentration and horizontal extent of the gas migration. Depending on the size and depths of these wells it may be necessary to apply a negative pressure to remove the gas.

For the control of gas venting at the surface of the landfill, a collection system incorporated into the cover is recommended. This would consist of a layer of permeable coarse granular material immediately under the final cover with a network of gravel trenches and collection pipes to conduct the gas to topographic highs where it could be burned, vented or collected (see Figure 4-3). It is important that if a low permeable final cover is not used, that the granular material used to collect gas be at least 2 orders of magnitude more permeable than the cover. Otherwise gas may tend to migrate vertically up through the cover.

Since final contours of the site have not been determined, existing contours have been used for the conceptual design. The only major change that would be required by a change in the contours would be that the collection points would be moved to the new topographic highs. Depending on the type of system and the number and location of vents/collection points, it may be necessary to apply negative pressure to remove the gas.

An alternative methane collection system could consist of methane collection wells, drilled at sufficient spacing within the landfill to vent the build-up of methane beneath the cover. However, it is considered that these wells will not tolerate defletions to the extent that flexible pipe will, and thus long-term maintenance may be economically unattractive.

We understand that studies are being conducted by representatives of the owner to determine the feasibility of collecting methane generated at the landfill for commercial use. These studies were not available for this report. The conceptual methane gas management system presented above centralizes the gas collection points and could possibly be incorporated into the commercial recovery system. However, significant changes may be required depending upon the final design of a commercial system. If commercial recovery is not utilized, then methane must be vented or burned in a controlled manner.

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4.5 FINAL GRADE CONTOURS

We understand discussions are currently taking place between the City of Seattle, the City of Kent and the landowners concerning the final contours of the site. Thus, in our analyses we have assumed that existing contours are representative of those at closure.

Contour grading of the landfill is a simple and effective means for controlling surface infiltration. Grading the landfill to a profile of a maximum of 12 percent and a minimum of 6 percent with side slopes no steeper than 20 to 25 percent will allow surface water to drain from the site and will minimize infiltration (Tolman, 1978). If the minimum slopes are not compatible with the intended final land use, then subsurface drains may be required to control infiltration. The final surface configuration of the landfill should be designed to permit drainage even after settlement of the landfill (estimated to be up to 20 to 25%). It may be necessary to continually maintain the surface grade during the first 5 to 10 years after closure when the settlement will be greatest.

Any final land use that is planned for the Kent Highlands landfill must accommodate the required contour grading of the site, the expected settlements, periodic maintainance and the methane gas control system.

4.6 FINAL COVER DESIGN

Various types of artificial and natural material can be used as a final cover material. Impermeable covers such as concrete, asphalt and synthetic liners are very expensive and would typically only be required when the toxicity level of the waste

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material is extremely dangerous to public health (Kastman, 1981). We recommend that the soil cover system consist of a moderate to low-permeability cover material which is overlain by topsoil and a vegetative cover.

Details concerning selection and placement of a low permeability cover are discussed in Part I of this report. If a moderate permeability cover (on the order of 10^{-5} cm/sec) is used, similar requirements for thickness and compaction should be followed.

Samples of material from the abandoned sand and gravel operation located just north of the Kent Highlands site were tested to determine their feasibility as a final cover. Test results are presented in Part I. Tests indicated permeability values around 10^{-5} cm/sec. This would be unacceptable for a low permeability cover which is intended to reduce infiltration. However, at the Kent Highlands site this may not be a requirement and a material of this permeability may be acceptable.

5.0 MONITORING PROGRAM

Recommendations for various monitoring programs at the Kent Highlands site are given below. Monitoring of groundwater quality, leachate levels and settlement of the landfill are discussed in detail. Monitoring of surface water and methane gas will be addressed in more detail in the closure plan.

5.1 SURFACE WATER

In general, surface water quality should be regularly monitored to determine if it is being adversely affected by the landfill after closure. Specific details of the monitoring program should be worked out with the Washington Department of Ecology (WDOE) and the Health Department.

Surface water should be monitored at any location that it discharges from the site, namely the un-named creek (see Figure 5-1). If initial monitoring indicates that leachate is present in the surface water at this point then additional points should be sampled to further pin-point the source of the leachate.

It is expected that either quarterly or monthly sampling and analysis of surface water for basic leachate indicators will be sufficient. More complete chemical analysis may be required initially after closure and then on an annual or other basis.

5.2 GROUNDWATER

5.2.1 Regulatory Requirements

The requlatory requirements governing groundwater monitoring at the Kent Highlands site are the same as those discussed in Part I for the Midway landfill.

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To date, evidence indicates that groundwater east of the toe drain and buttress is not contaminated and that near-surface contamination may be a result of the contamination that existed before placement of the toe drain. Legal responsibilities and requirements for mitigation of the existing leachate are not clear. This problem must ultimately be resolved by discussion between the City of Seattle and the appropriate regulatory agencies. It is expected that monitoring of existing pollution will be a minimum requirement.

5.2.2 Monitor Well Locations

WDOE standards require at least one upgradient and two downgradient monitor wells. Recommended locations of monitor wells are shown in Figure 5-2. This array will provide upgradient and downgradient monitoring at the site. The existing monitor wells below the toe drain are incorporated into this system. Six additional monitor wells are recommended: one approximately 300 feet west of the landfill to monitor upgradient quality; and three north and two south of the landfill. More wells may be required in the future depending upon the data collected from the three additional monitor wells recommended herein.

Piezometers and test wells that are still existing from previous investigations should continue to be monitored. These installations will provide useful information pertaining to water levels around the site.

5.2.3 Monitor Well Construction

Monitor wells should be constructed to comply with regulatory standards and guidelines including:

- Well casing and screen should be made of a relatively non-reactive material. PVC is generally acceptable, most metals are not;

- PVC solvent or cement should not be used for plastic well casing and screen;

- Wells should be drilled using air, water, or a biodegradable mud as the circulating fluid and properly developed to remove any contamination introduced during drilling;

- The annulus of each well should be sealed to prevent surface water inflow;

- The top of each well should be equipped with a locking cover.

Wells at dangerous waste sites are required to be a minimum of 4 inches in diameter to allow easy sample collection. Size requirements at municipal landfills are uncertain. The WDOE has indicated that smaller wells (e.g., 2-inch) may be acceptable if devices are provided which can sample small diameter wells. A schematic of a typical monitor well is shown in Figure 5-3. Proposed methods of monitor well construction should be approved by the WDOE before wells are actually installed.

5.2.4 Water Sampling and Analysis

Water samples can be taken by bailing or pumping the monitor wells. The sampling device should be thoroughly cleaned before use and should be constructed of materials which will not chemically alter the sample.

Prior to collecting a water sample, a minimum of three well volumes of water should be removed from the well. If the well is in low yield materials, it is generally sufficient to pump the well dry once and let it refill before collecting the sample. As water is removed from the well its temperature, conductivity and pH should be checked periodically. These parameters should stabilize before collecting a sample.

Sampling procedures should be established in cooperation with the laboratory responsible for the chemical analysis. Generally the laboratory can provide sample bottles with preservatives already added. Chemical analyses should be conducted by an EPA certified laboratory.

Semi-annual sampling of monitor wells should be sufficient although a final determination of sample frequency should be made in coordination with the WDOE.

It is recommended that initially, a complete chemical analysis of each well be made which will establish conditions at closure. Thereafter it should be sufficient to analyze only for major leachate indicators. If significant increases in indicators are noted more complete analysis may be required. A representative list of chemical constituents is given in Table 5-1. The final list should be developed in cooperation with WDOE.

Table 5-1
Recommended Groundwater Analysis

1. <u>Parameters Analyzed Semiannually</u>

Temperature	Chloride
pH	Iron
Conductivity	COD
Color	TDS
Turbidity	TSS

2. <u>Additional Parameters Analyzed Initially</u>

Hardness	Arsenic	TOC
Alkalinity	Barium	BOD
Acidity	Cadmium	*Chlorinated Hydrocarbons
Phosphate	Chromium	**Chlorophenoxys
Sulfate	Copper	
Ammonia as N	Lead	
Nitrate as N	Manganese	
Nitrite as N	Mercury	
Sodium	Selenium	
Fluoride	Silver	
Calcium	Zinc	
Odor	Cyanide	
Potassium	Foaming Agents	
Magnesium		

* Endrin, Lindane, Methoxychlor, Toxaphene
** 2,4-D, 2,4,5-TP Silver

5.3 METHANE GAS

The EPA In their Criteria for Classification of Solid Waste Disposal Facilities (FR September 13, 1979) state that the concentration of explosive gases should not exceed:

- o Twenty-five percent of the lower explosive limit for gases in facility structures (excluding gas control or recovery systems);

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- The lower explosive limit for gases in soil at the property boundary. (The lower explosive limit for methane gas in air is about 4 percent by volume.)

These are criteria not regulations, and thus are not specific requirements for a closure system. The closure system will incorporate a methane gas collection and management system which will be designed to prevent offsite migration through the ground. However, it is not possible to guarantee 100 percent methane collection, thus a gas monitoring system should be established.

Figure 5-4 shows possible locations of a gas monitor wells around the periphery of the site. Figure 5-5 shows a typical gas monitor well design. Any final designs for a gas monitor well system should be developed in cooperation with WDOE and the Health Department.

5.4 SETTLEMENT

Decomposition and consolidation of the landfill will result in significant settlements. It is not possible to predict the amount of settlement beforehand. However it is useful to monitor settlement in order to mitigate adverse affects (such as altered surface drainage, cracking of cover material) and to project long term trends.

An annual aerial topographic survey would provide the desired information. If annual aerial surveys are not practicl due to cost or other considerations, settlement should be monitored by setting up approximately 12 monitor stations on the landfill. Locations should be chosen once final contours and landuse are determined. Each station would typically consist of a 2 foot by

2 foot steel-reinforced concrete block, about 12 inches thick and buried at least several inches into the ground. The elevations of each station should be surveyed at least once a year.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The stratigraphy at the Kent Highlands site consists of the landfill materials underlain by glacial drift deposits of sand to gravel. These are underlain by stream/lake sediments of clay and silt to clean fine sand. Exposed on the south bank of the ravine in which the landfill is located is a stratified silt which is believed to underlie most of the site. At the toe of the landfill there are fine sand deposits underlying peat deposits.

2. The groundwater table is sloping down from the west towards the Green River. Prior to the landfill, seeps were observed on the north bank at approximately elevation 100. Below this elevation the groundwater is very close to the pre-landfill ground surface. Groundwater north and south of the landfill is flowing towards the center of the ravine.

3. High concentrations of methane gas were identified in coarse-grained glacial deposits which are in contact with the landfill along its western perimeter. The extent of gas migration out of the landfill to the west is not known.

4. Offsite surface water is currently being diverted around the site. Onsite surface water is being conducted into settlement ponds before discharging into the Geen River.

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5. Groundwater/leachate is being collected by a leachate collection system within the landfill and by a drain placed in the toe buttress located at the base of the eastern slope of the landfill. Springs which once entered the ravine on the northern slope are being collected and conducted by pipes to a leachate treatment pond. This pond also accepts the leachate collected in the leachate collection system and the toe drain. The water in the treatment pond is subjected to primary treatment and then discharged into Metro sewer lines.

6. Following closure, the landfill should be capped with a moderate to low permeability cover to reduce leachate production and to control methane migration. A methane collection system should be incorporated into the soil cover design. Recommendations for the design of these systems are presented in Sections 4.3 and 4.5.

7. The existing groundwater/leachate collection system and the spring drain collection system at the Kent Highlands landfill are currently operating adequately. However, long-term performance of the system, particularly the spring drains is uncertain. Conceptual recommendations to insure that the existing systems continue to operate effectively (presented in Section 4.2) include replacement of the spring drain line and/or the placement of monitoring wells to monitor water levels adjacent to the spring drains and the spring drain line and continued monitoring of the toe drain.

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8. A long term monitoring program should be implemented which includes periodic chemical analysis of surface water and groundwater which exit the site. Monitoring should also include methane gas migration and settlement of the landfill. A suggested monitoring plan and schedule are presented in Section 5.0.

9. Depending on the various closure elements that are incorporated into the final design, additional evaluations may be required including:

   - Further assessment of gas migration;
   - Permeability characteristics of landfill materials;
   - Further testing of potential cover materials;
   - Laboratory water quality analysis.

Respectfully submitted,

GOLDER ASSOCIATES

Charles W. Lockhart

Jerry Rowe

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REFERENCES

Brunner, Dirk R. and Daniel J. Keller, 1972, Sanitary Landfill Design and Operation, U.S. Environmental Protection Agency. SE-287.

Environmental Protection Agency, 1979. National Secondary Drinking Water Regulations. Federal Register, Vol. 44, No. 140.

Environmental Protection Agency, 1979. Criteria for Classification of Solid Waste Disposal Facilities and Practices; Final, Interim Final, and Proposed Regulations, Federal Register, Vol. 44, No. 179.

Environmental Protection Agency, 1975 and 1976. National Interim Primary Drinking Water Regulations. Federal Register, Vol. 40, No. 248 and Vol. 41, No. 133.

Head, K.H., 1980. Manual of Soil Laboratory Testing, Vol. 1, Pentech Press.

Kastman, Kenneth H., 1981. Remedial Actions for Waste Disposal Sites. Fourth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, pp. 131-150. Madison WI., Department of Engineering and Applied Sciences Unviersity of Wisconsin - Extension.

King County Board of Health. Rules and Regulations Establishing Minimum Functional Standards for Solid Waste Handling; Prohibiting Certain Conduct. Seattle, WA, KCBH.

King County Department of Public Works, Division of Hydraulics, May, 1979. Storm Drainage Control; Requirements and Guidelines. Seattle, WA, KCDPW.

Lambe, T.W., 1951. Soil Testing for Engineers, New York, N.Y., John Wiley and Sons, Inc.

Lutton, R.J., et al., 1979. Design and Construction of Covers for Solid Waste Landfills. U.S. Environmental Protection Agency. EPA-600/2-79-165.

Luzier, J.B., 1969. Geology and Groundwater Resources of Southwestern King County, Washington. Department of Water Resources, Olympia, Washington.

Richardson, J.W., Bingham J.W., and Madison, R.W., 1968. Water Resources of King County. U.S.G.S. Water Supply Paper 1852, U.S. Government Printing Office, Washington D.C.

Snyder, D.E., P.S. Gale and R.F. Pringle, 1973. Soil Survey King County Area, Washington, U.S. Department of Agriculture Soil Conservation Service in Cooperation with Washington Agricultural Experimental Station.

Tolman, Andrews L., et al., 1978. Guidance Manual for Minimizing Pollution from Waste Disposal Sites, U.S. Environmental Protection Agency. EPA-600/2-78-142.

Washington State, 12/31/72. Washington Adminstration Code, Regulations Relating to Minimum Functional Standards for Solid Waste Handling, Chapter 173-301.

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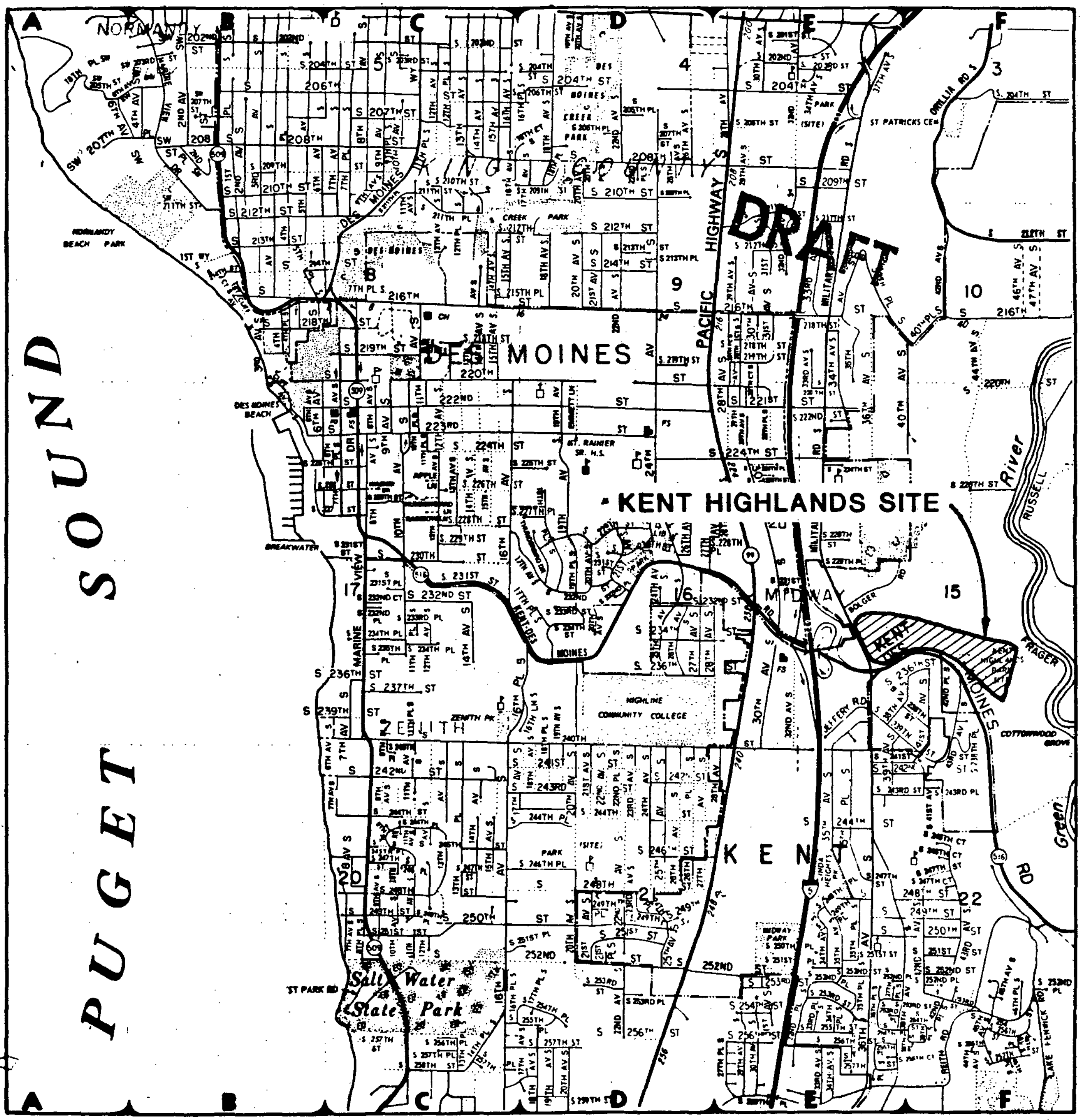
LOCATION PLAN – KENT HIGHLANDS LANDFILL

Figure 1-1



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Scale, miles

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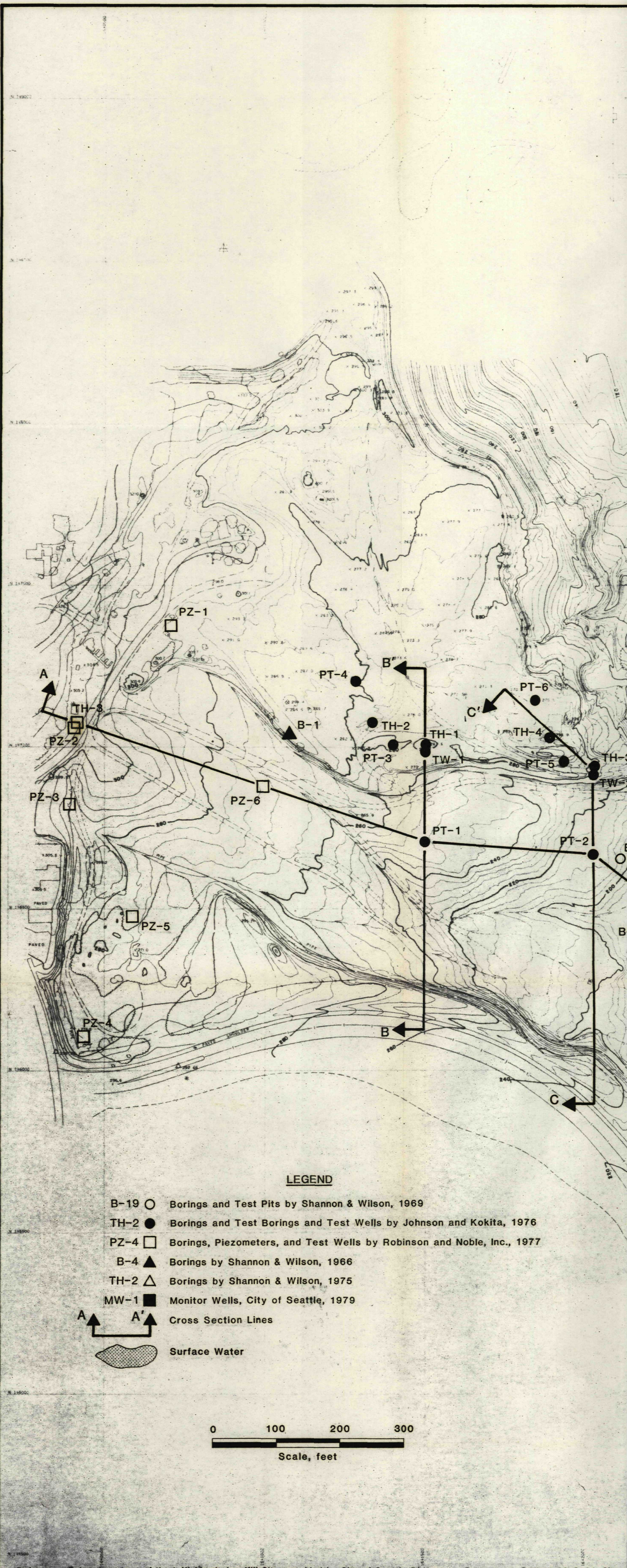
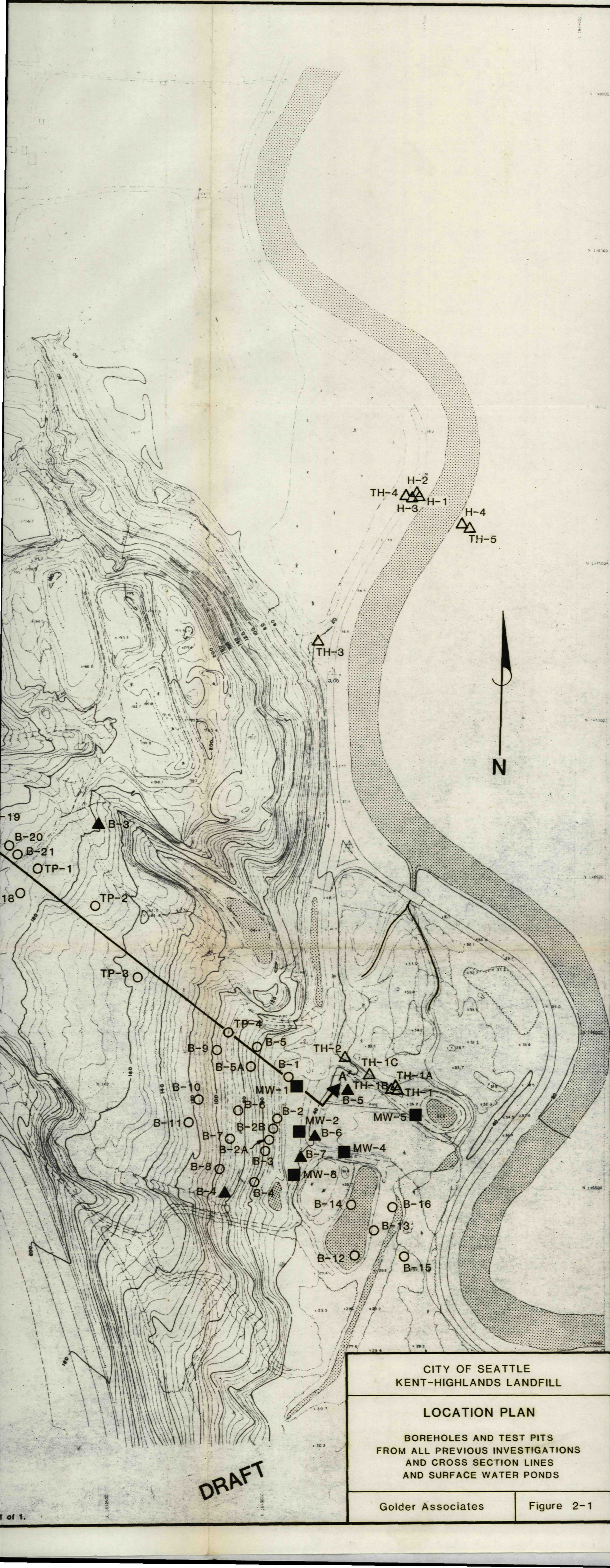
FIG 2.1



Reference: Taken from topo of Kent-Highlands Landfill Site, provided by City of Seattle Engineering Department, Project 82-6164, Sheet

T813-1276-060 June 82 PC



CITY OF SEATTLE
KENT-HIGHLANDS LANDFILL

LOCATION PLAN

BOREHOLES AND TEST PITS
FROM ALL PREVIOUS INVESTIGATIONS
AND CROSS SECTION LINES
AND SURFACE WATER PONDS

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FIG 3.1

KENT HIGHLAND LANDFILL
CROSS SECTIONS A-A', B-B' & C-C'

Figure 3-1

LEGEND

Surface of Fill, 1982	
Ground Surface, 1973	
Ground Surface, 1982	
Inferred Extent of Geologic Units	
2-4-76 / 109.5	Water Level Elevation (feet), Date of Reading
Unit 1	Landfill
Unit 2a & b	Glacial Drift a) Silty SAND with some gravel to fine to medium SAND b) Sandy GRAVEL to silty SAND and GRAVEL
Unit 3a & b	Stream/Lake Sediments a) CLAY and SILT to SILT, trace sand and gravel b) Clean fine SAND to silty fine to medium SAND, some gravel
Unit 4	Clayey SILT with fine sand seams to gravelly CLAY and SILT
Unit 5	Stratified SILT

TH-1 Piezometer Completion
Sealed Section
Open Section

For location of cross sections, see Figure 2-1.

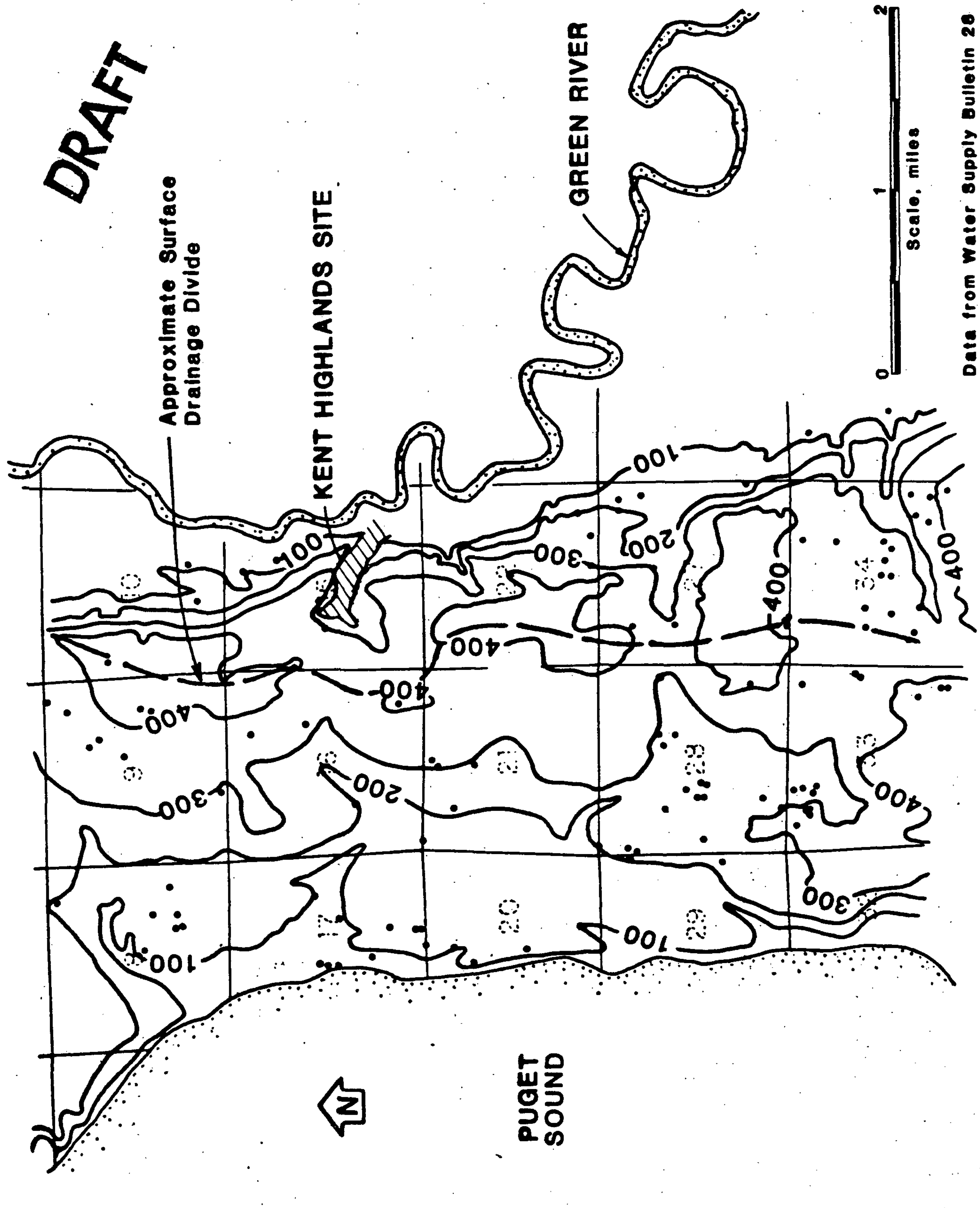
* Robinson and Noble, Inc., 1977 ** Johnson and Kokita, 1976 *** Shannon and Wilson, 1969: No Piezometer Completion.

SPECIAL NOTE:
Data concerning the various strata have been obtained at the exploration locations only. The soil stratigraphy between these locations has been inferred from geological evidence and so may vary from that shown.

* Robinson and Noble, Inc., 1977 ** Johnson and Kokita, 1976 *** Shannon and Wilson, 1969: No Piezometer Completion.

GROUND SURFACE CONTOURS

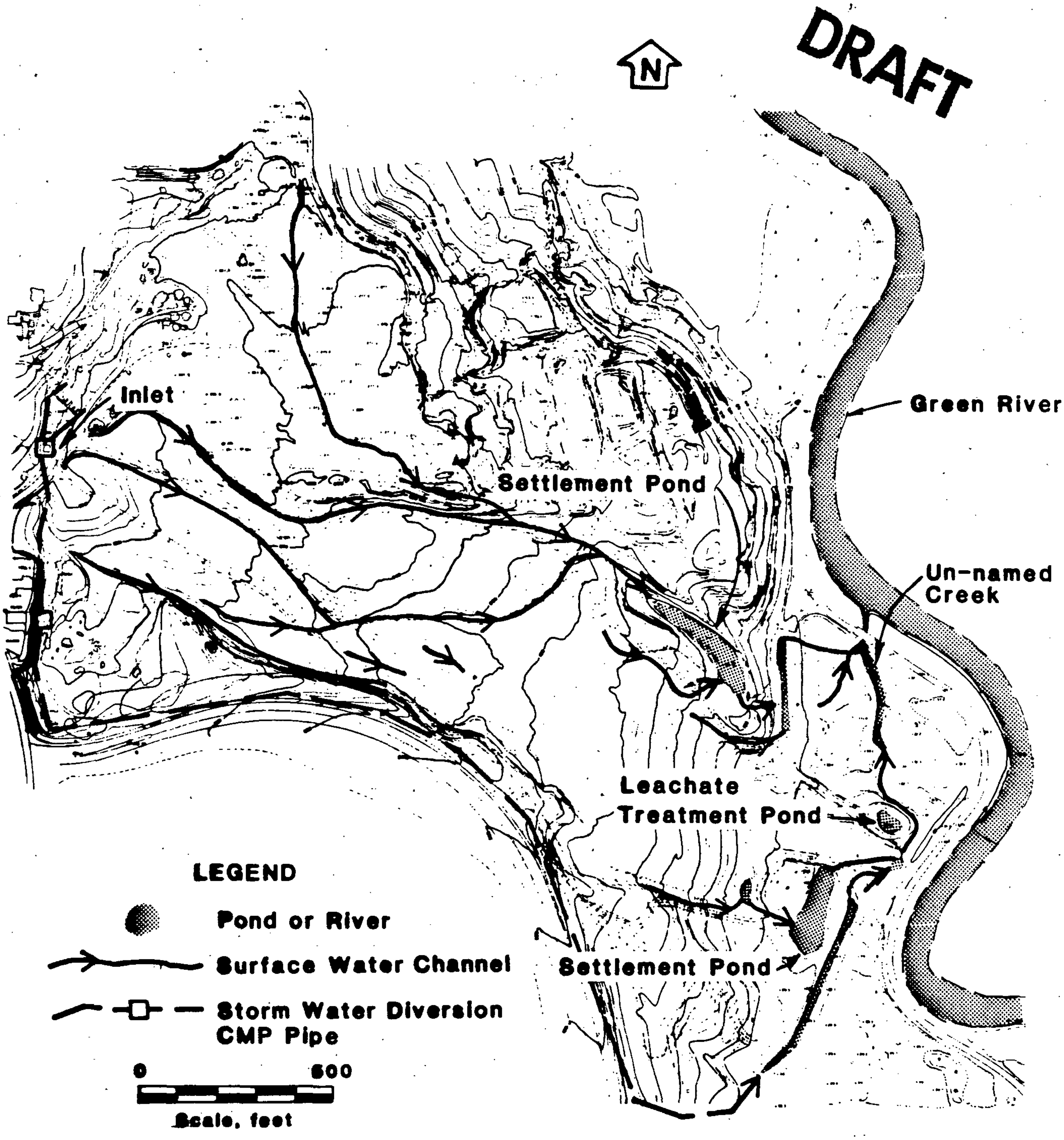
Figure 3-2



Rev.
Dwg. No. A813-1276-046 Date June 82 Eng. P.C.

SURFACE WATER DRAINAGE

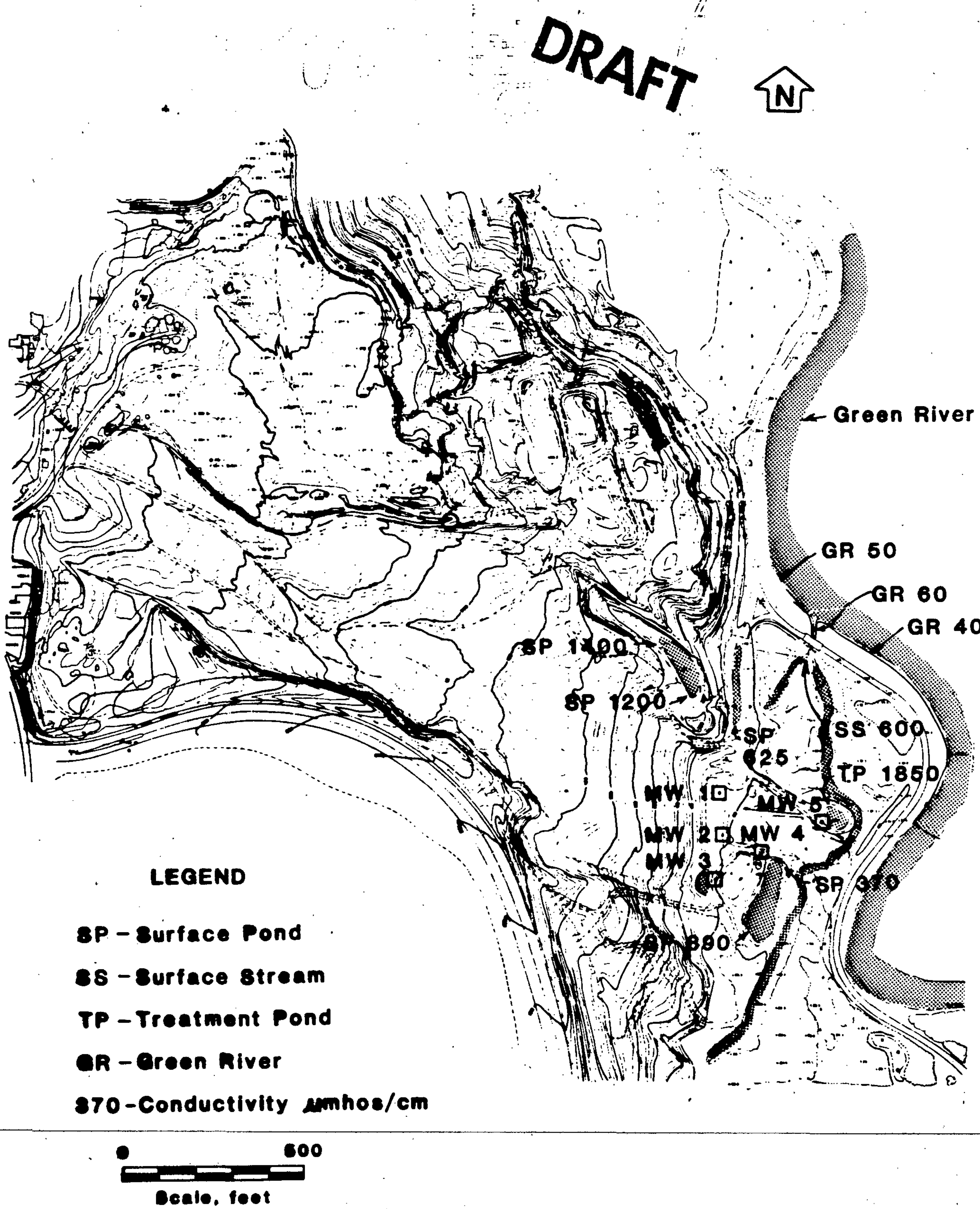
Figure 3-3



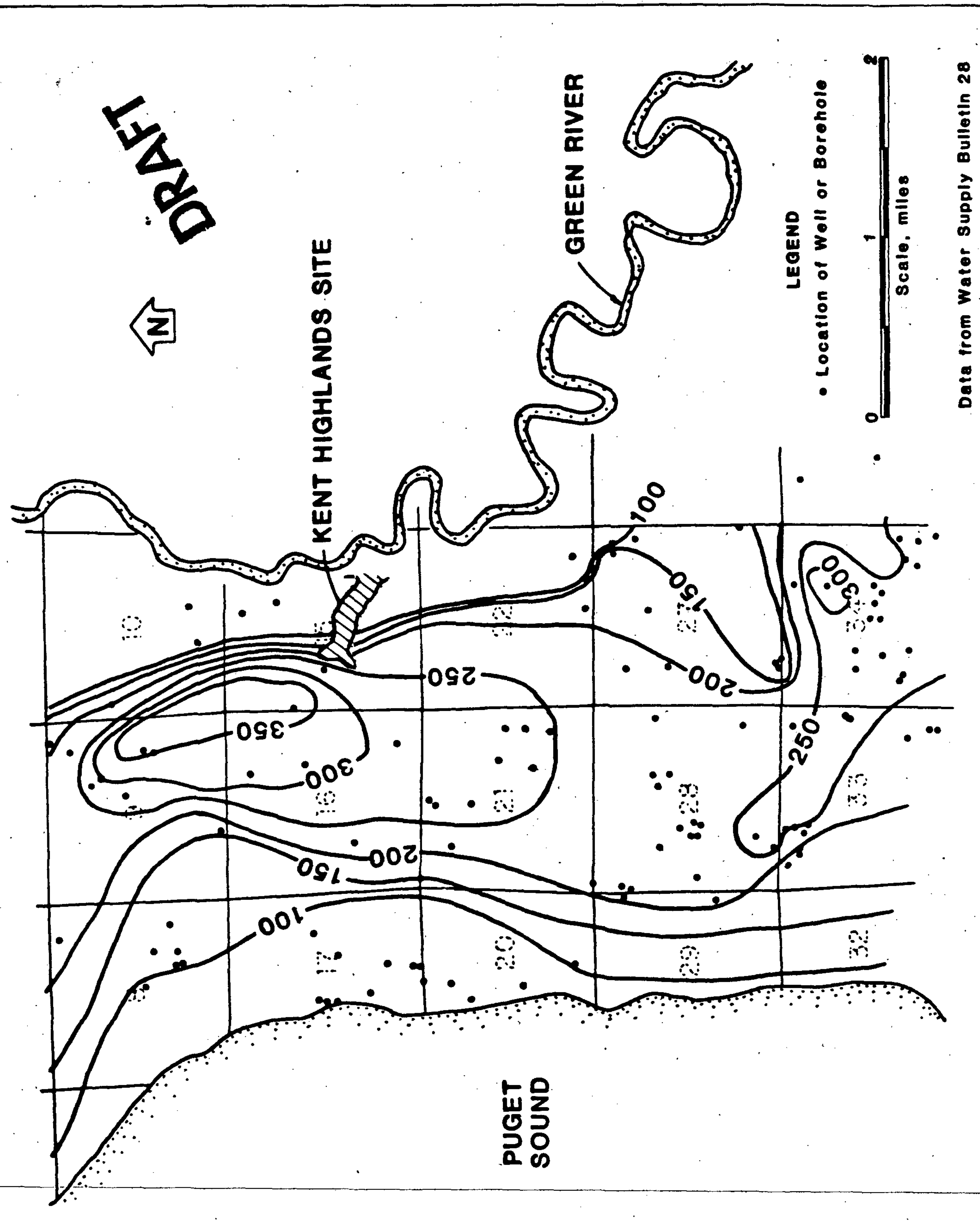
Rev. Dwg. No. Date Eng.

CONDUCTIVITY SURVEY - SURFACE WATER

Figure 3-4



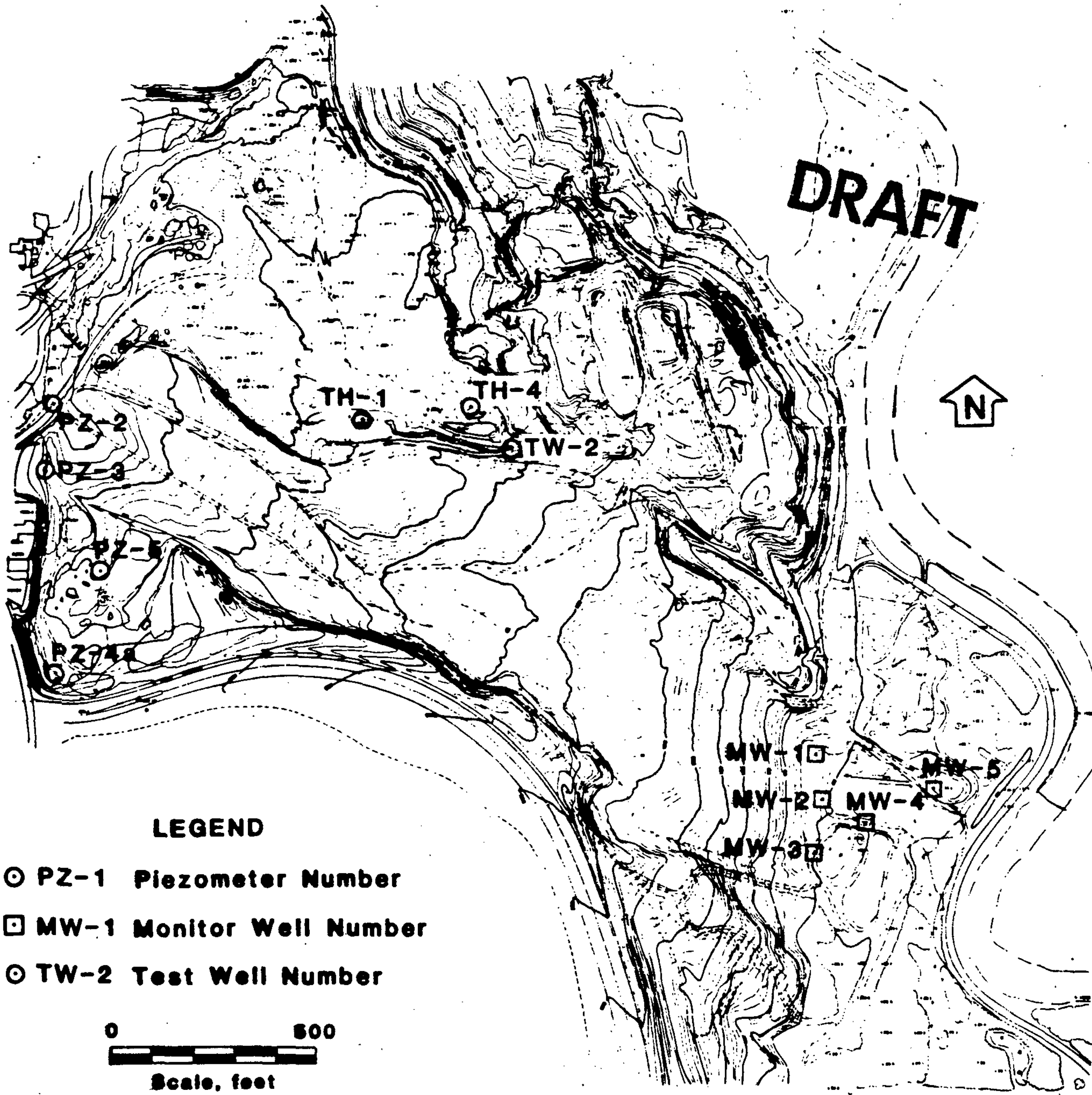
APPROXIMATE REGIONAL WATER LEVEL CONTOURS — Figure 3-5



Rev. ____ Dwg. No. A813-1274-048 Date June 82 Eng. P.C.

GROUNDWATER ELEVATIONS

Figure 3-6



LEGEND

⊙ PZ-1 Piezometer Number

⊡ MW-1 Monitor Well Number

⊙ TW-2 Test Well Number

0 500

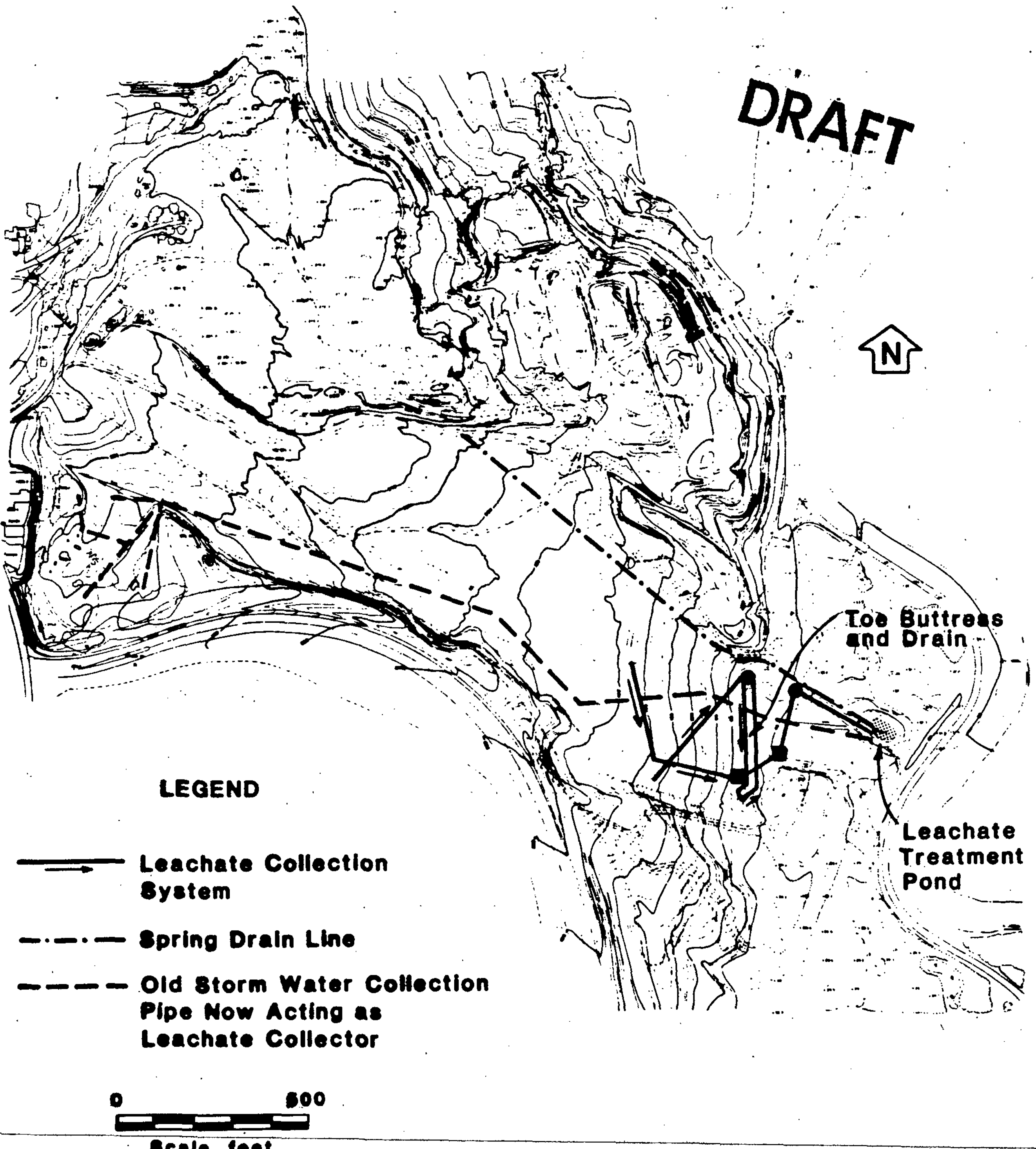
Scale, feet

Groundwater Elevation(ft)/ Completion Elevation(ft)

PZ-2	a=153.3/25.3
	b=197.3/105.3
PZ-3	a=184.2/48.2
	b=182.2/99.2
PZ-4	a=238.2/80.8
PZ-5	229.5/79.0
TH-1	127.9/58.4
TH-4	120.2/53.5
TW-2	117.8/40
MW-1	40.7/25.6
	41.4/15.1
	41.9/4.3
MW-2	39.7/28.6
	39.3/14.8
	36.6/-0.5
MW-3	36.2/23.5
	37.6/2.9
	34.0/-1.5
MW-4	30.5/20.8
	32.2/11.6
	26.5/-5,4
MW-5	25.7/18.6
	24.3/10.1
	24.2/-3.4

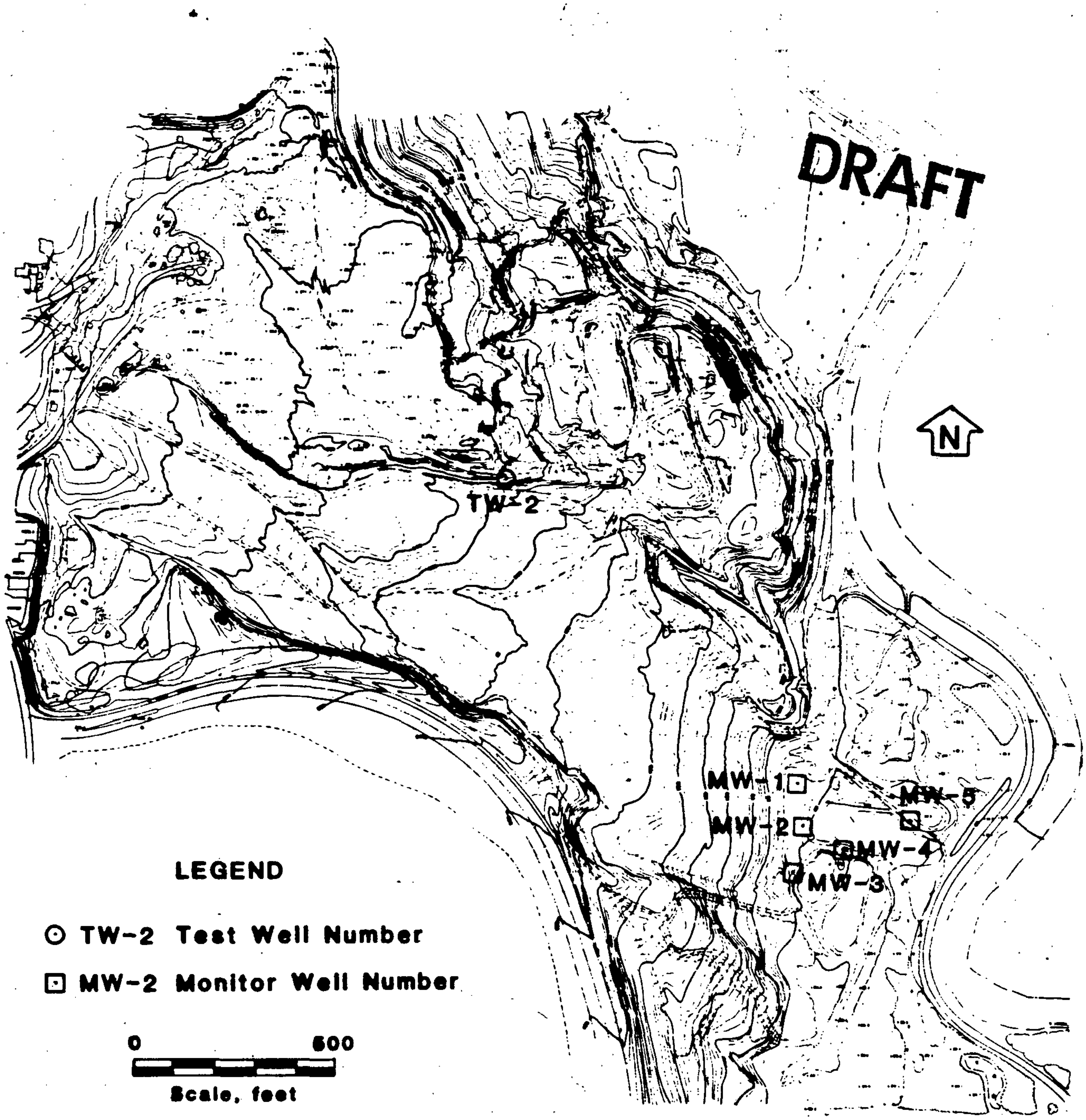
Rev. ____
Dwg. No. A815-1276-049 Date June 8- Eng. P.C.

SPRING DRAINS AND LEACHATE COLLECTION SYSTEM Figure 3-7



Note: Corrugated ABS plastic drainpipe for leachate and gas collection not shown.

Rev. ____ Dwg. No. AR17-1274-050 Date July 92 Eng. RC

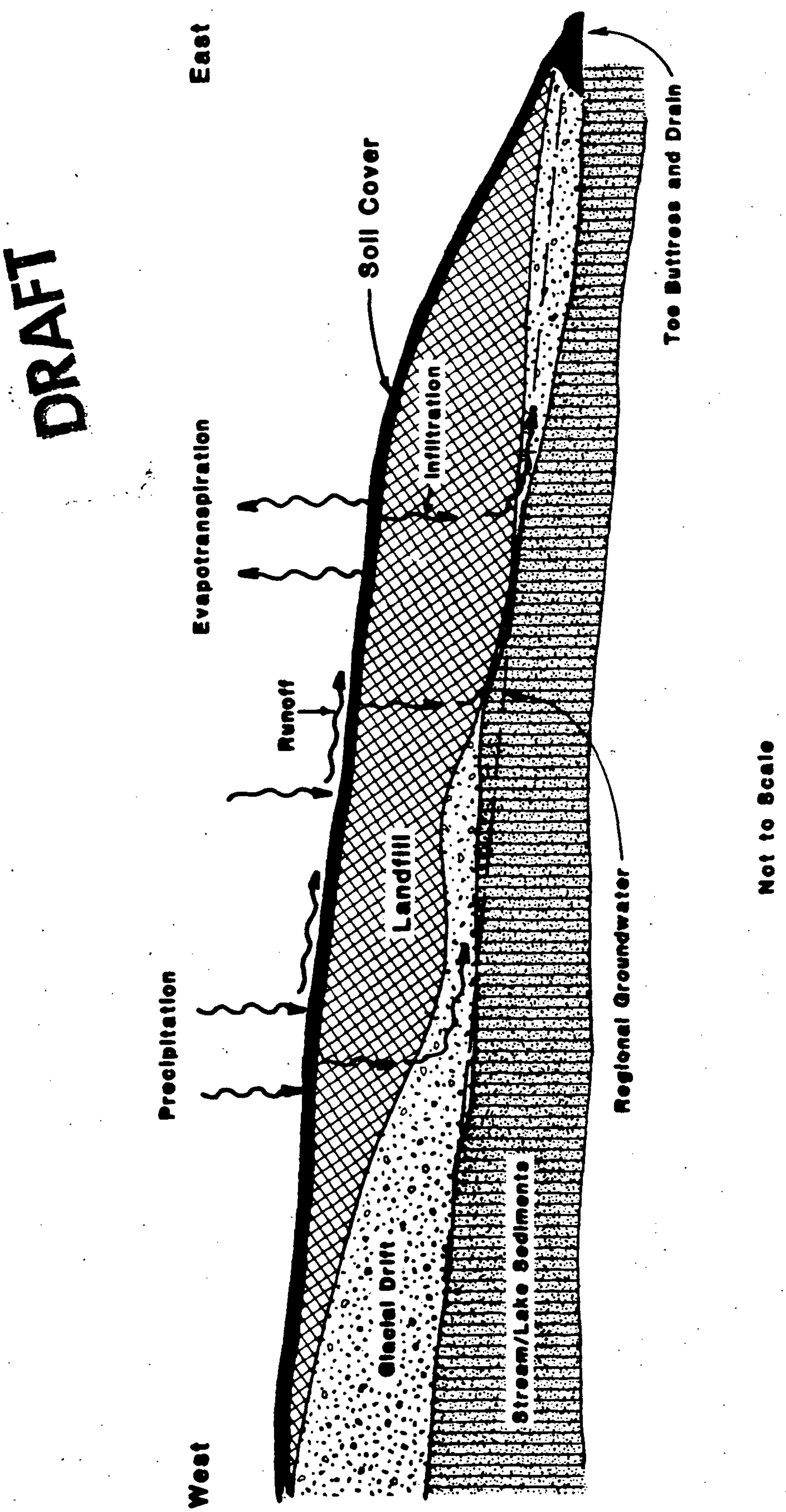


Conductivity (µmhos/cm) Completion Elevation (ft)

MW-1	240/25.6	MW-4	610/20.8
	142/15.1		370/11.6
	130/4.3		110/-5.4
		MW-5	920/18.6
MW-2	900/28.6		600/10.1
	240/14.8		170/-3.4
	155/-0.5		
		TW-2	110/80-40
MW-3	700/23.5		
	290/2.9		
	130/-1.5		

Rev. ___ Dwg. No. A847-1274-051 Date June 82 Eng. P.C.

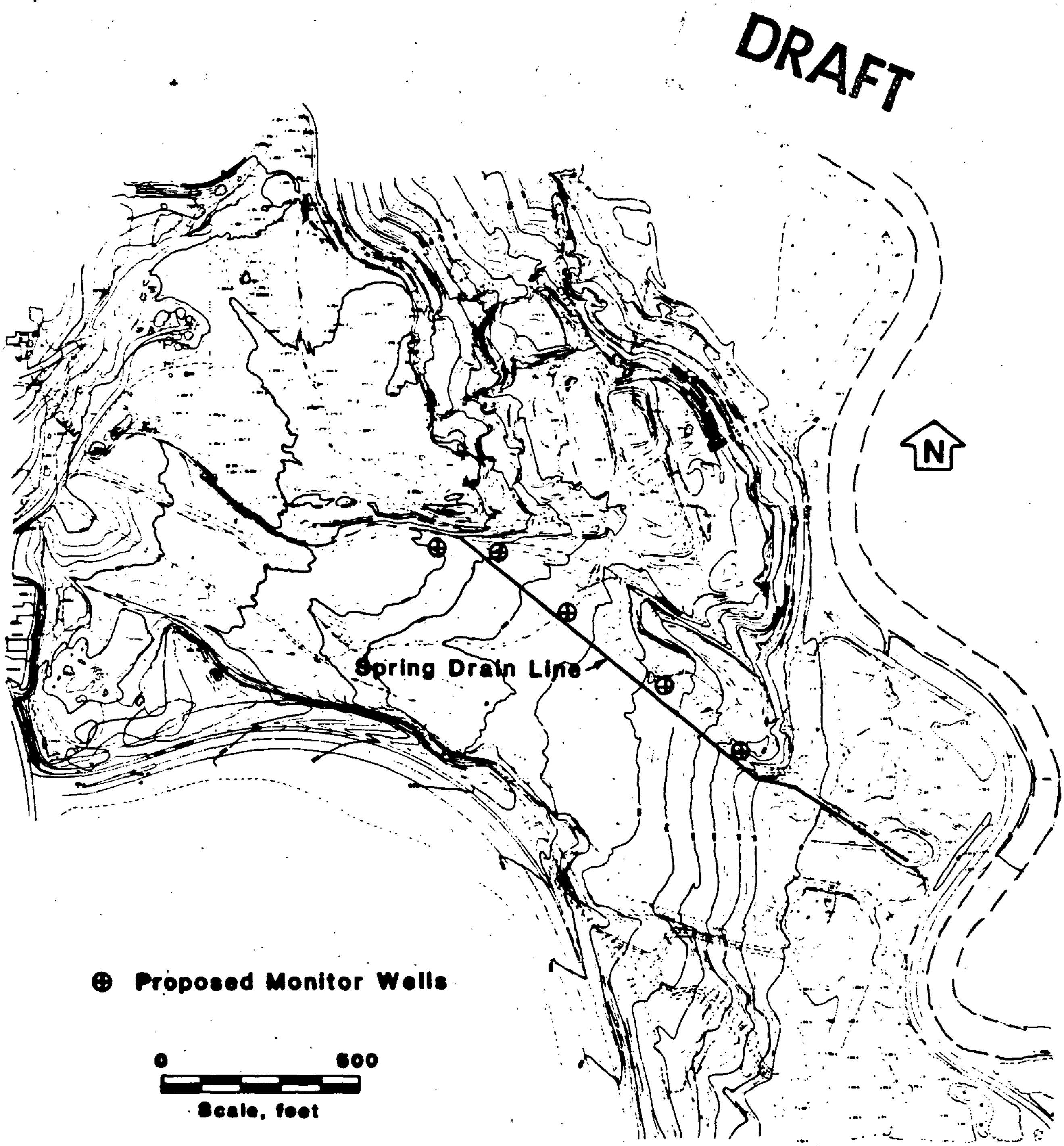
SCHEMATIC OF POST CLOSURE HYDROLOGIC SYSTEM　Figure 4-1



Rev.
Dwg. No. A813-1274-052 Date Eng.

PROPOSED SPRING DRAIN MONITOR WELL LOCATIONS

Figure 4-2

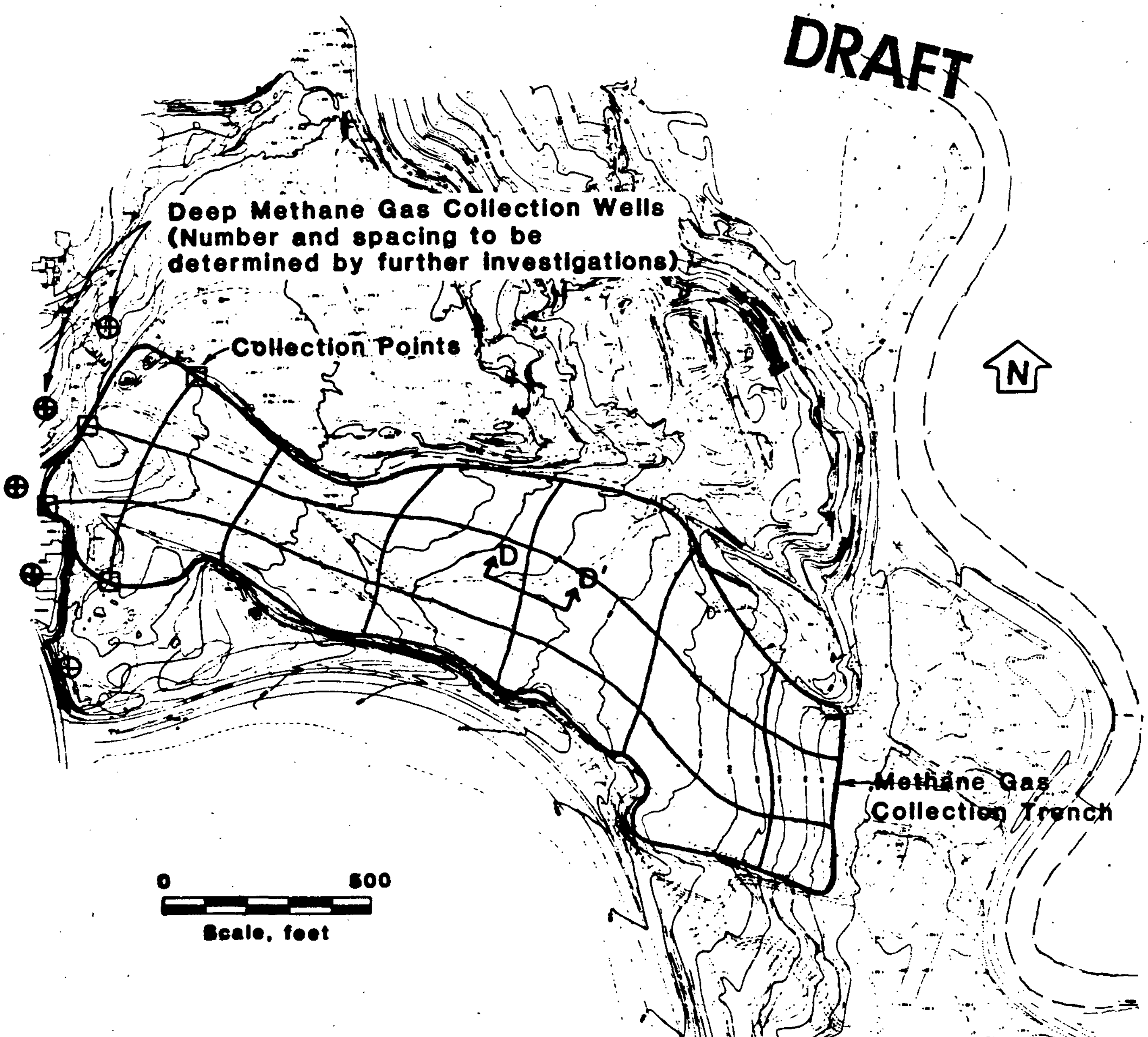


Rev. ____ Dwg. No. A 817-1276-057 Date June 82 Eng. P.L.

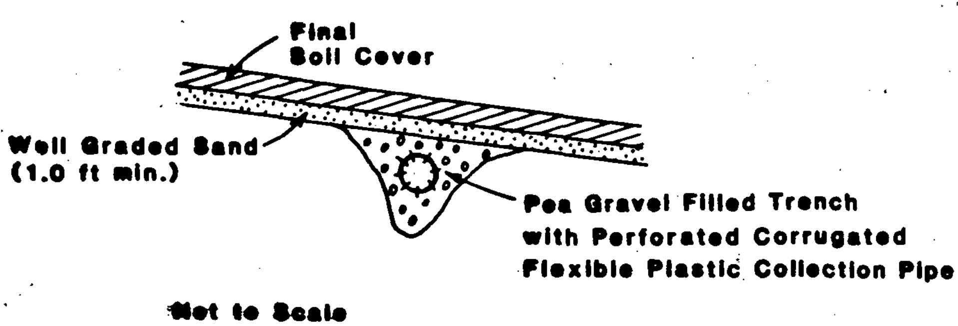
METHANE GAS COLLECTION SYSTEM

Figure 4-3

DRAFT



Cross Section D-D'
Methane Gas Collection Trench

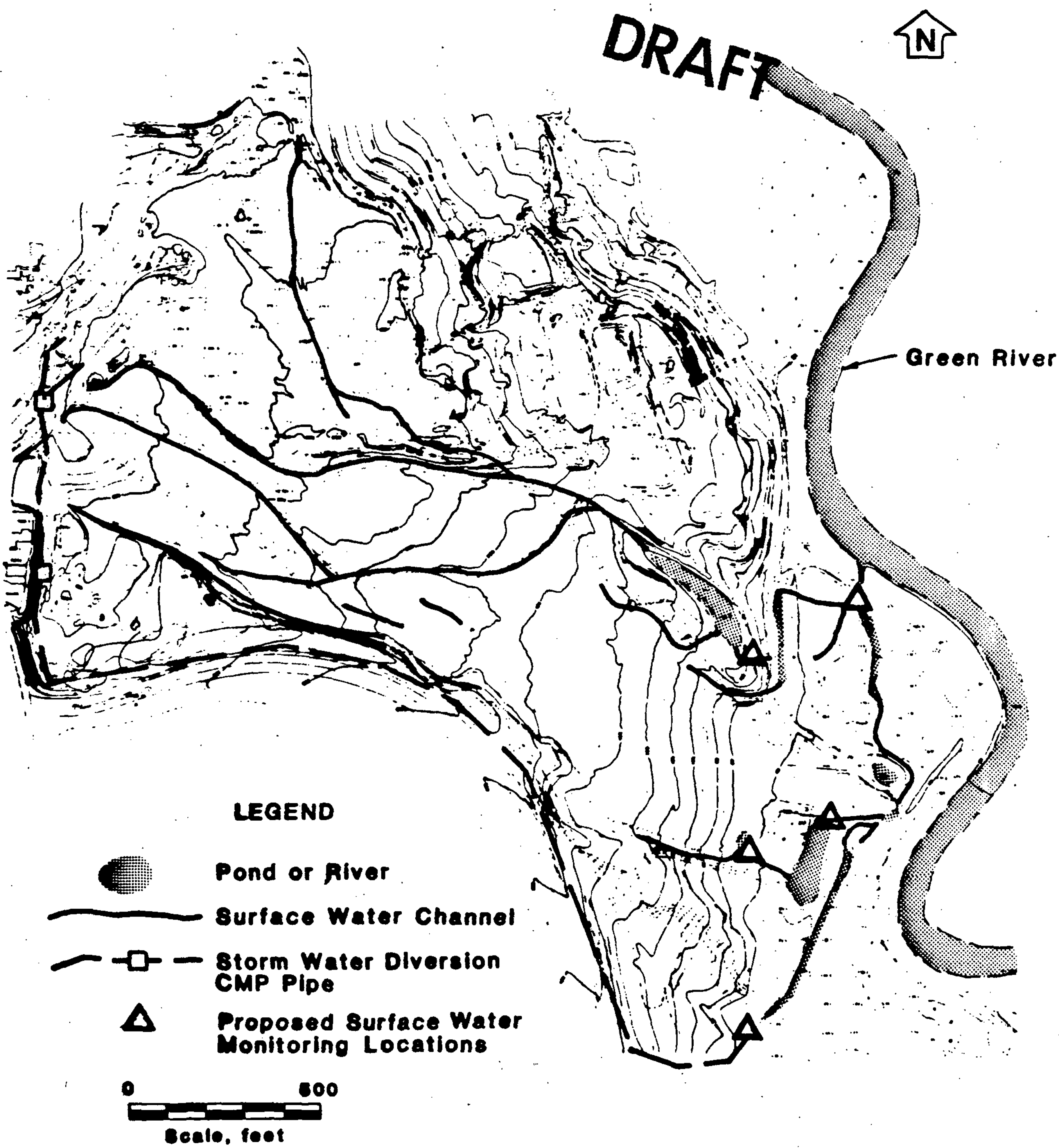


Not to Scale

Rev. ____ Dwg. No. A813-1276-072 Date June 82 Eng. PL

PROPOSED LOCATION OF SURFACE WATER MONITORING POINTS

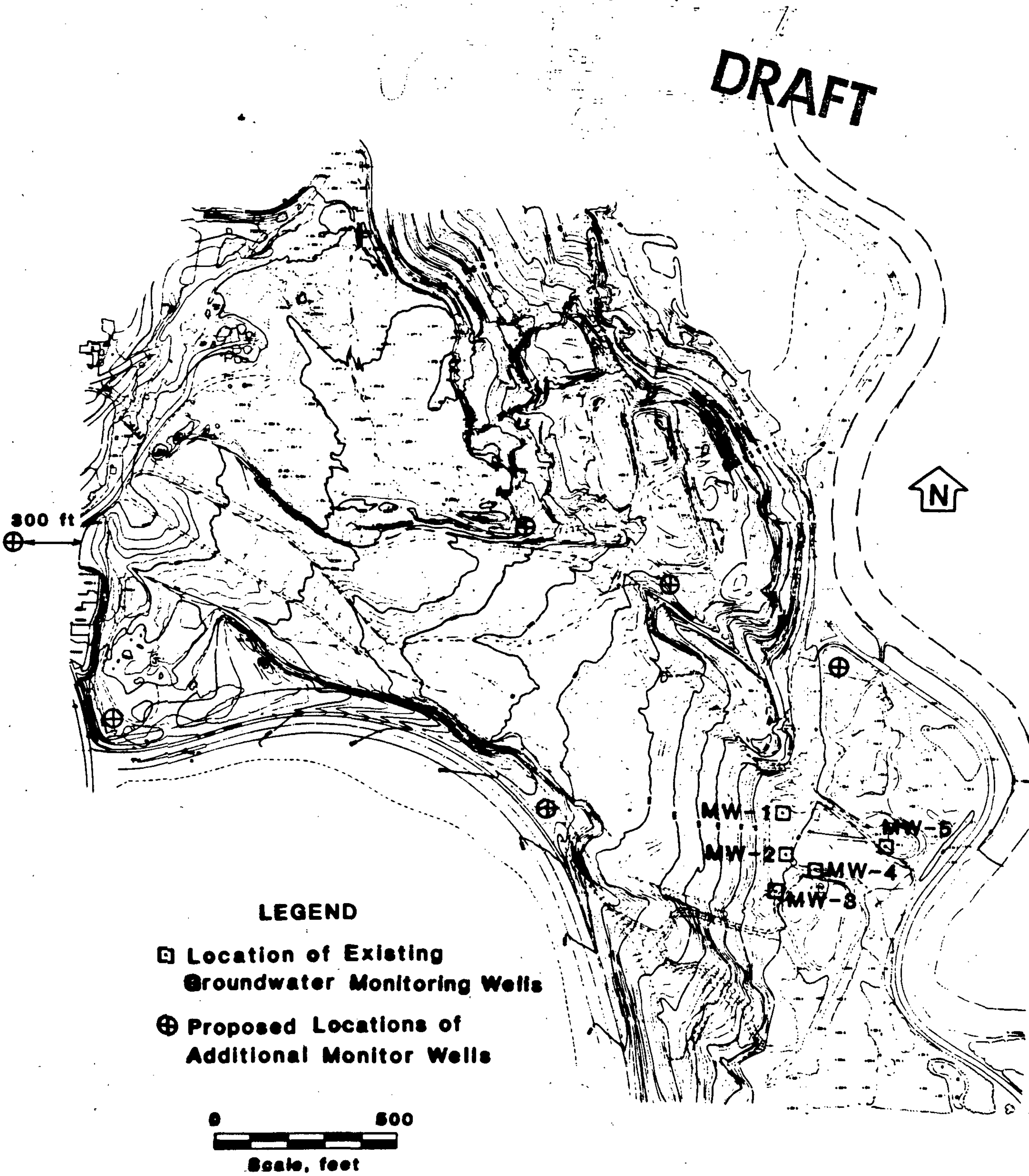
Figure 5-1



Rev. Dwg. No. Date Eng.

PROPOSED GROUNDWATER MONITOR WELL LOCATIONS

Figure 5-2

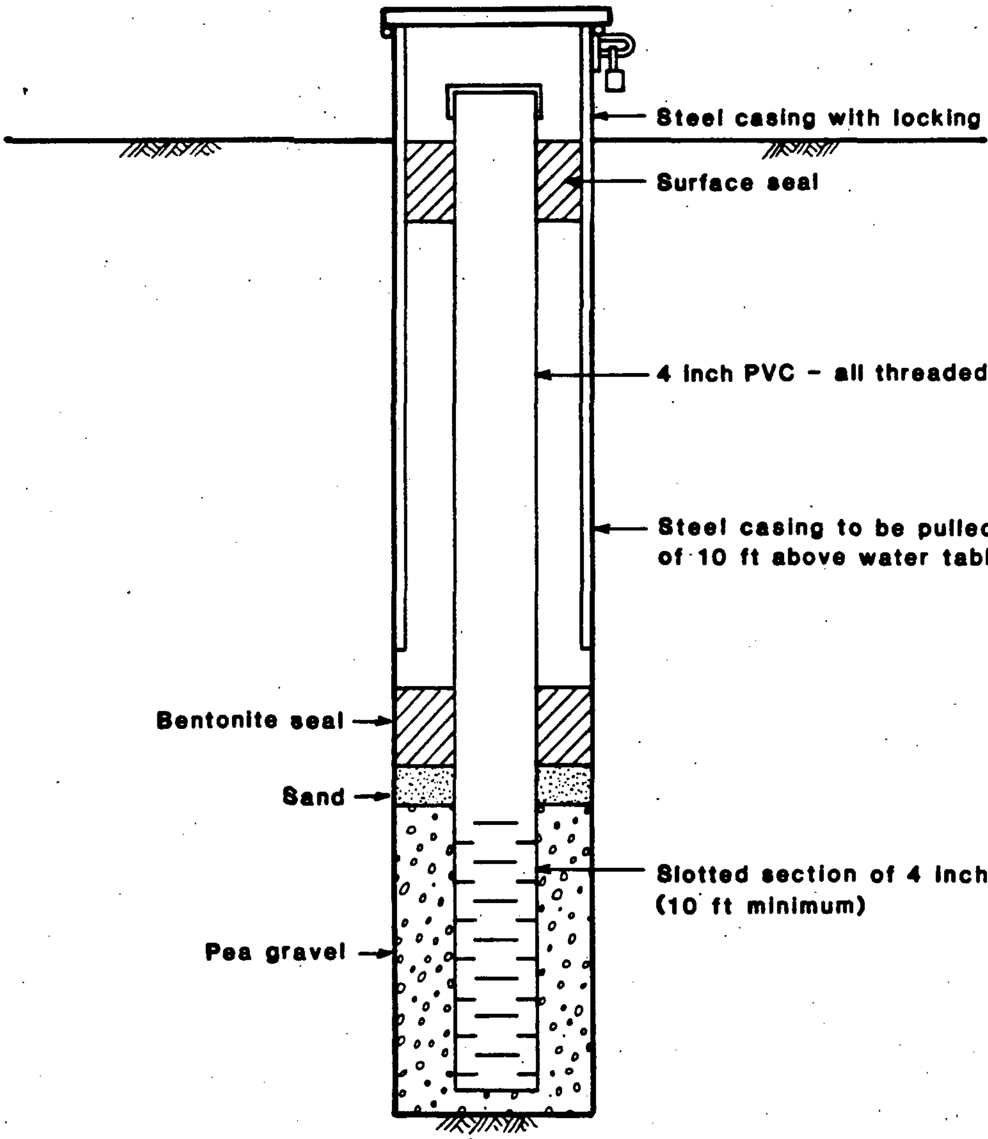


Rev. Dwg. No. A83-1276-054 Date June 8 Eng. P.C.

GROUNDWATER MONITOR WELL INSTALLATION

Figure 5-3

DRAFT

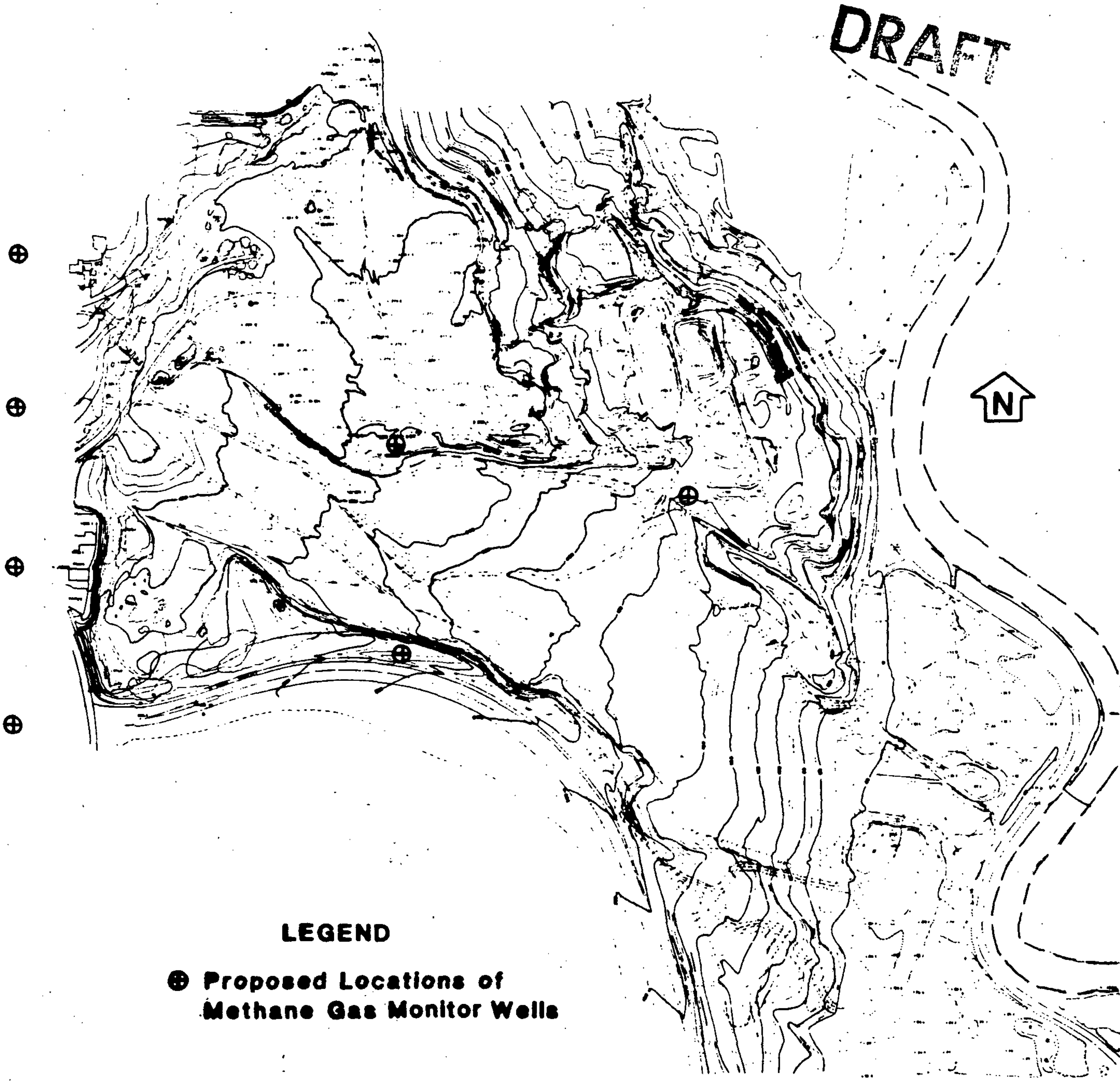


Not to Scale

Rev. ______ Dwg. No. AB13-1276-055 Date Jun 82 Eng. P.C.

PROPOSED METHANE GAS MONITOR WELL LOCATIONS

Figure 5-4



LEGEND

⊕ Proposed Locations of Methane Gas Monitor Wells

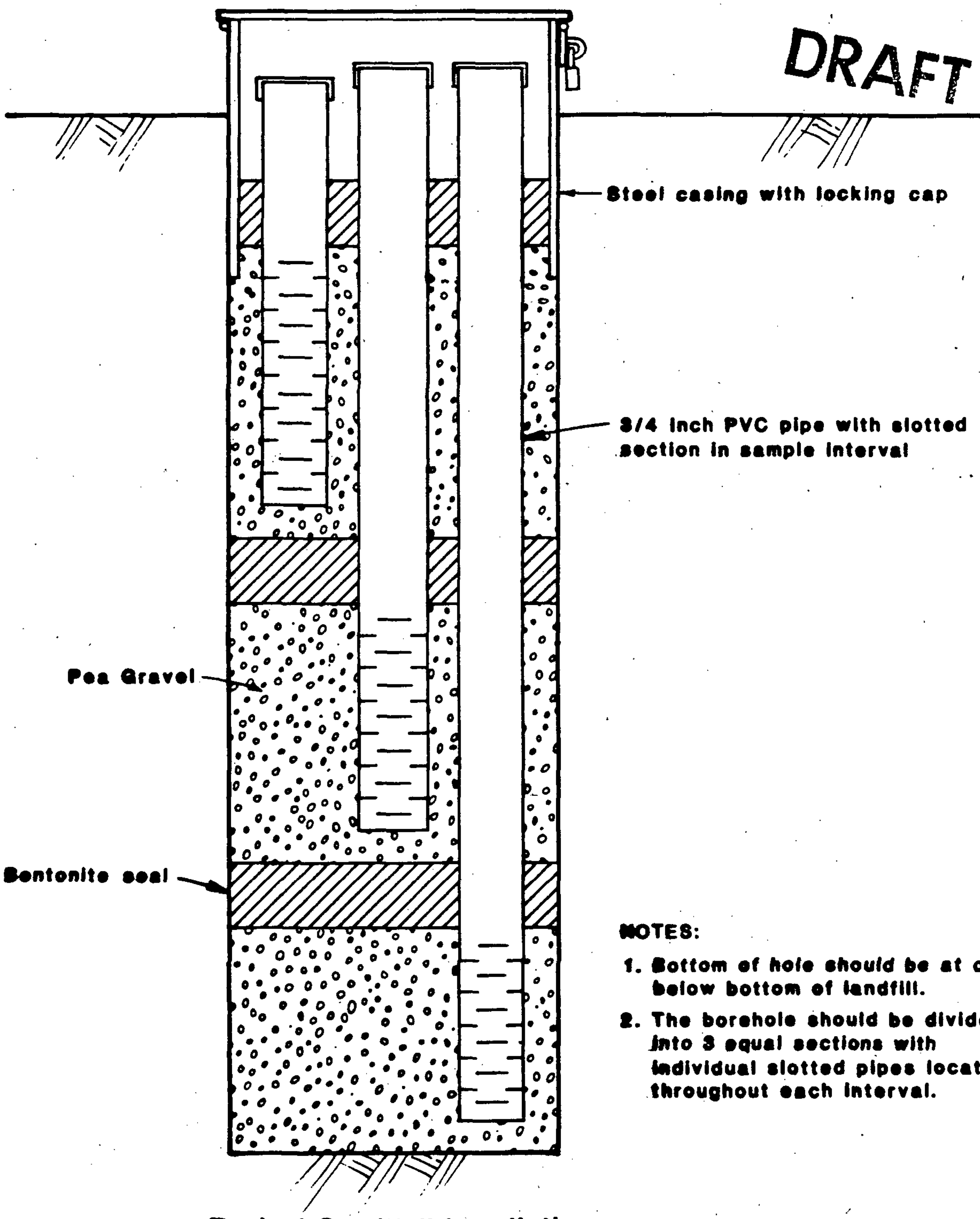
0 500

Scale, feet

Rev. ____ Dwg. No. A913-1276-056 Date June 82 Eng. PC

METHANE GAS MONITOR WELL INSTALLATION

Figure 5-5



NOTES:

1. Bottom of hole should be at or below bottom of landfill.
2. The borehole should be divided into 3 equal sections with individual slotted pipes located throughout each interval.

Typical Gas Well Installation

NOT TO SCALE

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APPENDIX A

DOCUMENTS OBTAINED FOR REVIEW

DRAFT

PART I - MIDWAY LANDFILL

Below is a list of all documents that were obtained and reviewed concerning the Midway site:

1) USGS Topographic Maps, 1968 and 1900

2) USGS Geologic Map of the Des Moines Quadrangle, Washington 1962

3) Air Photographs from 1936, 1946 and 1965

4) Geology and Groundwater Resources of Southwestern King County, Washington, Water Supply Bulletin No. 28, 1969.

5) Report from City of Seattle Engineering Department to Department of Highways Concerning the Proposed Landfill at the Midway Site, 1966.

6) Prints of Storm Drainage Facilities at the Midway Landfill and East of I-5.

7) Prints of 1966, 1981 and 1982 contours at the Midway Landfill.

8) Volume, Density and Remaining Life Analysis for Kent Highlands and Midway Landfill, URS Company, March 1981.

9) Midway and Kent Highlands Landfill Filling Strategies, URS Company, June 1981.

10) Water well logs, for Linda Heights and Cambridge water wells.

PART II - KENT HIGHLANDS LANDFILL

Below is a list of all documents that were obtained and reviewed concerning the Kent Highlands site.

1) USGS topographic maps 1968 and 1900

2) USGS geologic map of the Des Moines Quadrangle, Washington 1962

3) Air photographs from 1936, 1946 and 1965

4) Report on Sanitary Landfill Site No. 2 - Kent Highlands. Shannon and Wilson, Inc., 1966

5) Subsoil Investigation-Kent Highlands Sanitary Landfill, Kent, Washington. Shannon and Wilson, Inc., 1969

6) Subsurface Investigation Leachate Treatment Lagoon and Green River Pipeline Crossing Kent Highlands Sanitary Landfill, Kent, Washington. Shannon and Wilson, Inc., 1975

7) Soil Investigation and Well Pumping Tests at Kent Landfill, City of Seattle Engineering Department, I.K. Johnson and H.W. Kokita, 1976

8) Geohydrologic Study of Kent Highlands Landfill. Robinson and Noble, Inc., 1977

9) Drainage and Pollution Control Plan for the Kent Highlands Sanitary Landfill. Stevens, Thompson and Runyan, Inc., 1977

DRAFT

10) Topographic Contour Maps 1966, 1981 and 1982 of Kent Highlands Landfill

11) Kent Highlands Sanitary Landfill Leachate Collection and Toe Buttress - Phase 2, Location Drawings, 1978.

12) Piezometer and slope indicator monitoring data, City of Seattle Materials Laboratory.

DRAFT

APPENDIX B

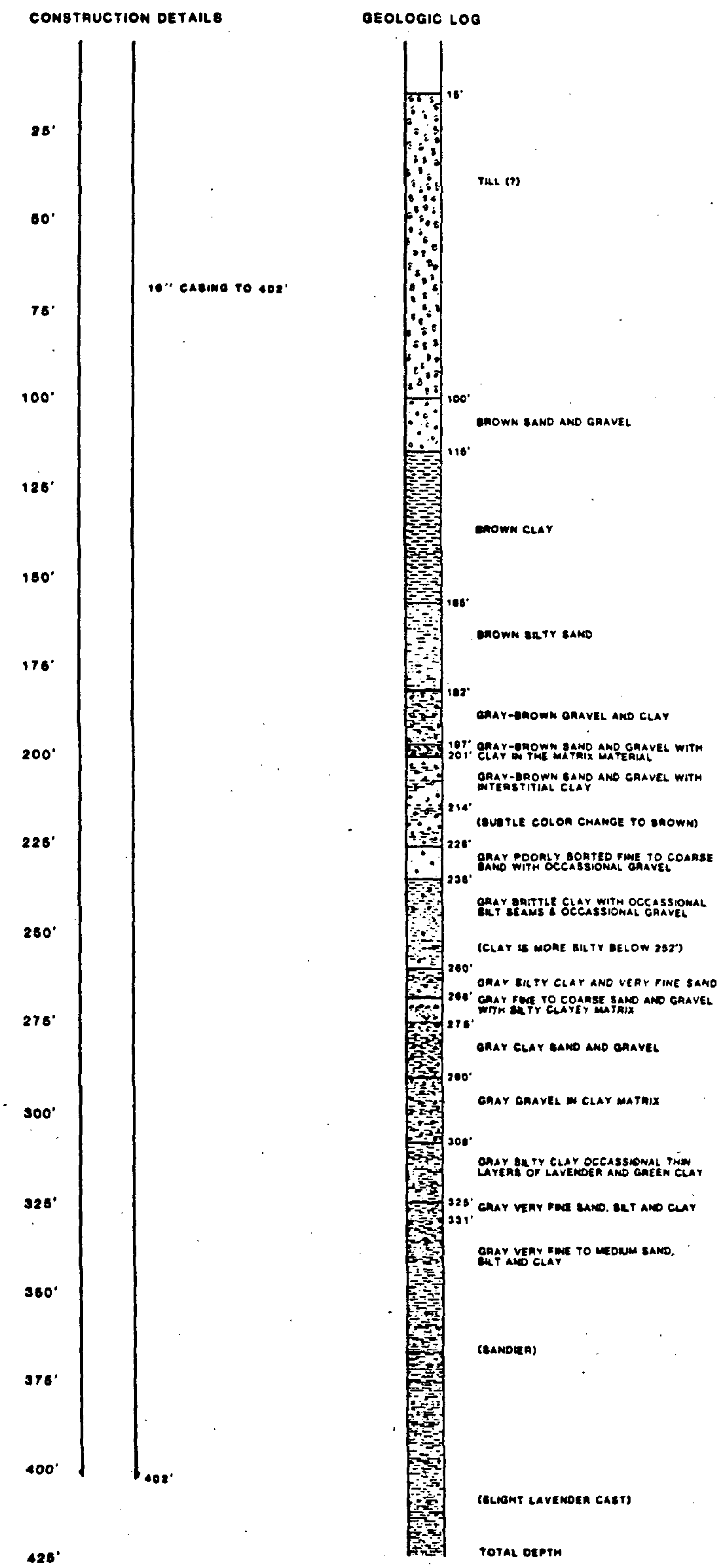
GEOTECHNICAL LOGS

DRAFT

LINDA HEIGHTS WELL - DRILLER'S LOG

CITY OF KENT
Linda Heights, Well B

JOB# 79-71B



DRAFT

ROBINSON & NOBLE, INC

From City of Kent

Golder Associates

Rev. ____ Dwg. No. 812-1276-442 Date June 82 Eng. P.C.

RECORD OF BOREHOLE BH-1

COORDINATES: N11,551.24 E9,147.62

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 15 January 1982

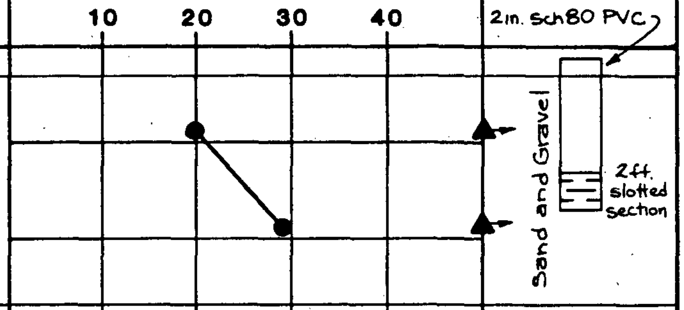
SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 3⅜ in. hollow stem auger

SOIL PROFILE			SAMPLES			
ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION
333.5 / 0						
331.5 / 2.0	Dense, brown and gray, coarse to fine SAND, some gravel					
	Very dense, brown and gray, coarse to fine SAND, some gravel, trace cobbles		S-1	2.0" D.O.	75/9"	330
			S-2	2.0" D.O.	50/4"	325
321.5 / 12.0	End of Hole					

● WATER CONTENT (%): 5, 10, 15, 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT: 10, 20, 30, 40

GAS SAMPLING WELL INSTALLATION



REMARKS: Hole terminated at 12.0 ft. due to auger refusal. No water in hole.
D.O. = 2in. Drive Open Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1

Dwg. No. A813-1276-001 Date Mar 82 Eng. P.C.

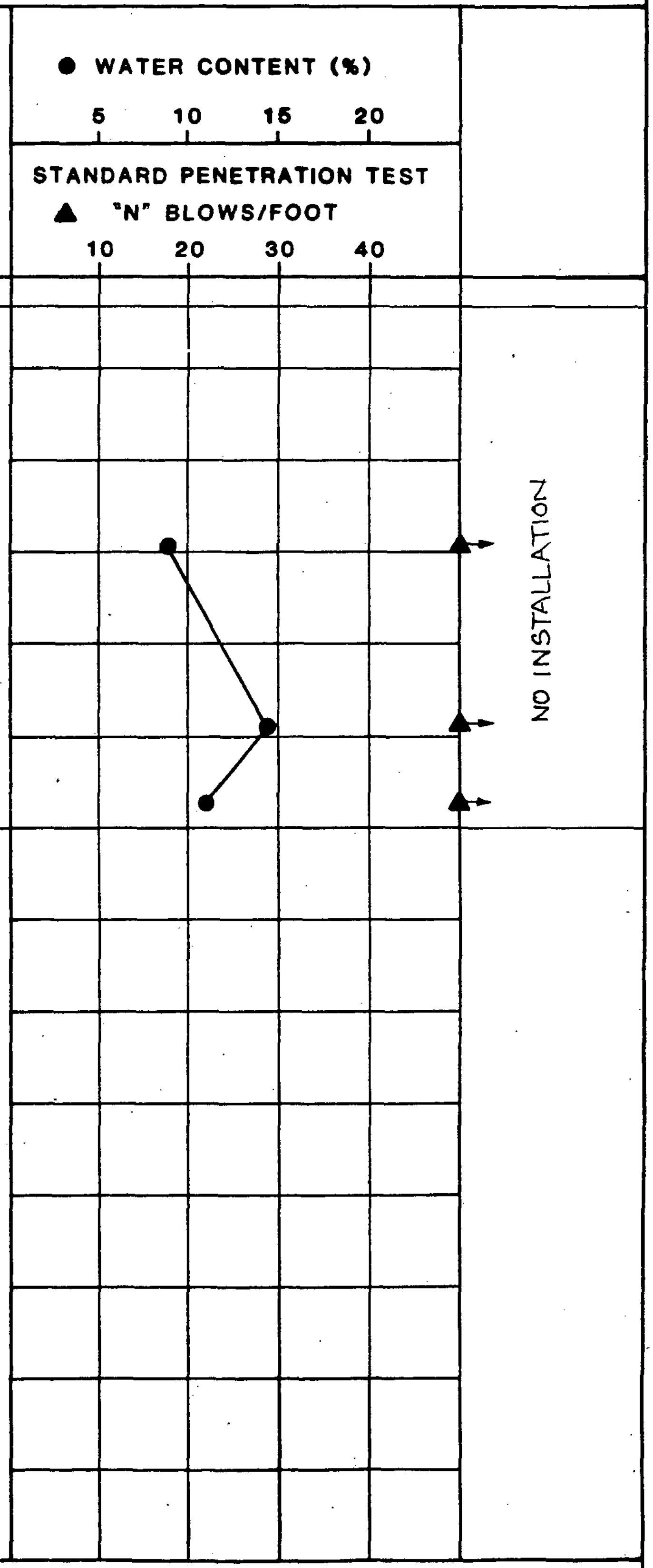
RECORD OF BOREHOLE BH-1A

COORDINATES: N 11,548 E 9,156 (approx.)

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 15 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 3⅜ in. I.D. hollow stem auger

SOIL PROFILE			SAMPLES				WATER CONTENT (%) / STANDARD PENETRATION TEST "N" BLOWS/FOOT
ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION	
335.5							
0							
331.5 / 2.0	Dense, brown and gray, coarse to fine SAND, some gravel						
	Very dense, brown and gray, coarse to fine SAND, some gravel, trace cobbles					330	
323.5 / 10.0						325	
321.5 / 12.0	Very dense, gray and brown GRAVEL and coarse to fine SAND		S-1	2" D.O.	50/3"	320	
	Very dense, gray and brown SAND and GRAVEL, trace clay, silt and cobbles to silty SAND and GRAVEL					315	
			S-2	2" D.O.	50/5"	310	
305.0			S-3	2" D.O.	50/3"	305	
28.5	End of Hole						



REMARKS: Hole terminated at 28.5 ft. due to refusal. No water in hole. Unable to take sample at 18.0 ft. due to boulder/cobble in hole. For water contents and standard penetration test results between 0 and 10 feet see BH-1.

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1

Dwg. No. A813-1276-011 Date Mar 82 Eng. P.C.

RECORD OF BOREHOLE BH-1B

COORDINATES: N 11,545.03 E 9,154.61

LOCATION: Midway Landfill DATUM: MSL DATE: 27 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. BORING METHOD: Mud Rotary

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION
333.1					
0	Gray and brown, medium to coarse SAND and fine to coarse GRAVEL with trace to some cobbles and boulders trace silt and fine sand	S-1	M.R.		330
		S-2	M.R.	7	325
		S-3	M.R.	–	320
		S-4	M.R.	15	315
		S-5	M.R.	30	310
		S-6	M.R.	45	305
		S-7	M.R.	45	300
		S-8	M.R.	30	295
		S-9	M.R.	30	290
284.1		S-10	M.R.	30	285
49.0	Gray and brown, fine to coarse SAND, medium gravelly, fine to coarse SAND, trace to some silt and clay	S-11	M.R.	30	280
274.1		S-12	M.R.	–	275
59.0	Gray and brown, medium to coarse SAND and fine to coarse GRAVEL with trace to some cobbles and boulders, trace silt and fine sand	S-13	M.R.	45	270
		S-14	M.R.	45	

STRAT. PLOT

● WATER CONTENT (%) 5 10 15 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40

PIEZOMETER COMPLETION

4 in. sch 40 PVC

Cement

REMARKS: M.R. = Mud Rotary Sample

▽ Water Level at 292.9 ft. on 9 Mar 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 2

Dwg. No. A813-1276-... Date Mar 82 Eng. P...

RECORD OF BOREHOLE BH-1B (contd.)

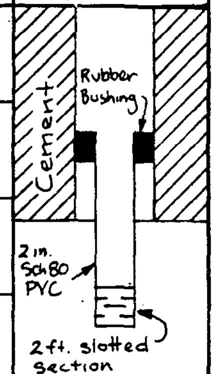
COORDINATES: N 11,545.03 E 9,154.61

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 27 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** Mud Rotary

SOIL PROFILE			SAMPLES				
ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION	WATER CONTENT (%) 5 10 15 20 / STANDARD PENETRATION TEST "N" BLOWS/FOOT 10 20 30 40
			S-15	M.R.	75	260	
254.1			S-16	M.R.	45	255	
79.0	Light to medium gray, silty CLAY to CLAY, some silt					250	
						245	
238.1						240	
95.0	End of Hole		S-17	2" D.O.	50/4"		

PIEZOMETER COMPLETION



REMARKS: M.R. = Mud Rotary Sample
D.O. = 2" Drive Open Sample

Water Level at 292.9 ft. on 9 Mar 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT**

Dwg. No. A813-1276-015 Date Mar 82 Eng. P.C.

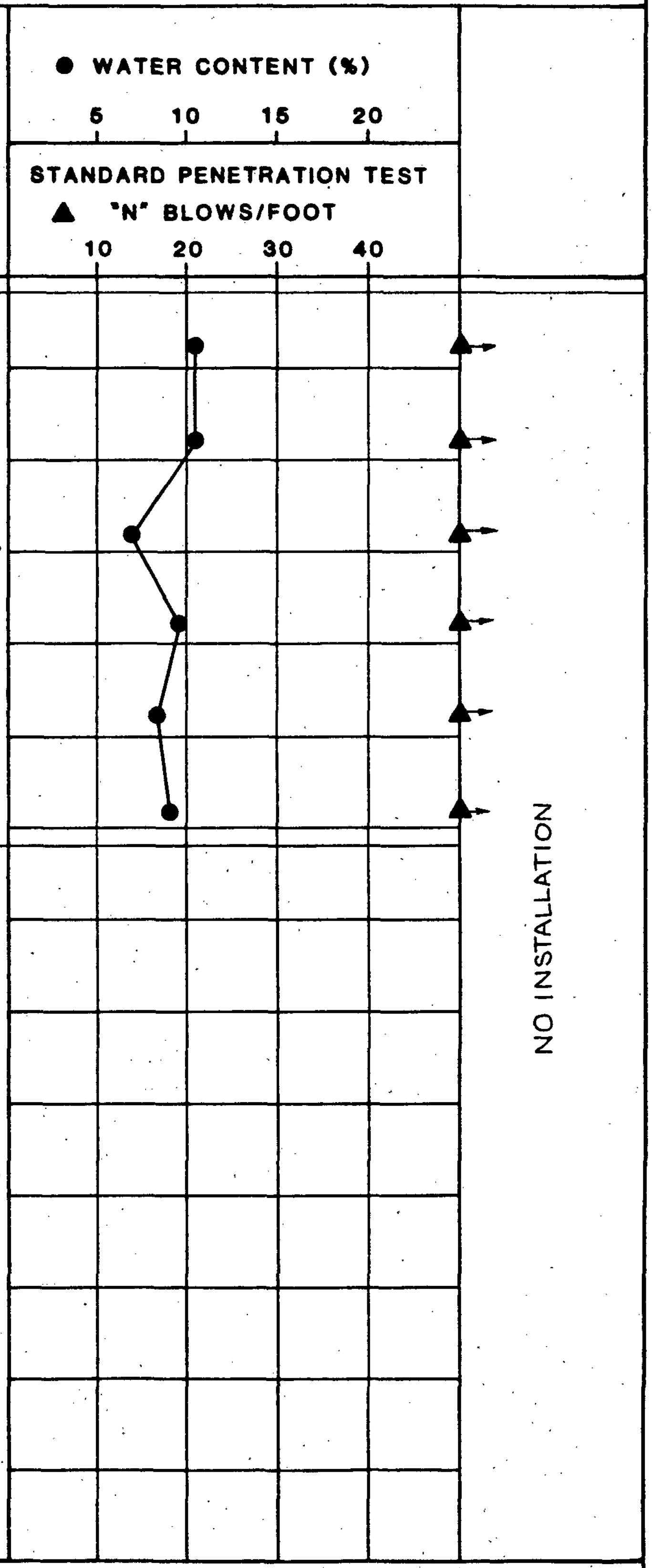
RECORD OF BOREHOLE BH-2

COORDINATES: N 10,548 E 9,080 (approx.)

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 15 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 3⅜ in. hollow stem auger

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.	ELEVATION
374.0 / 0	Compact, gray-green, coarse to fine SAND, trace to some silt and gravel	S-1	2" D.O.	50/4"	370
372.0 / 2.0	Very dense, gray-green, gravelly, coarse to fine SAND, trace to some silt and cobbles to coarse to fine SAND, some gravel, trace to some silt and cobbles	S-2	2" D.O.	50/4"	365
362.0 / 12.0	Very dense, gray, gravelly, medium SAND, some silt and cobbles	S-3	2" D.O.	50/3"	360
358.0 / 16.0	Very dense, gray SILT and fine SAND, some gravel, trace to some cobbles to silty fine to medium SAND, some gravel and cobbles	S-4	2" D.O.	50/4"	355
		S-5	2" D.O.	50/3"	350
		S-6	2" D.O.	50/3"	345
344.0 / 30.0	End of Hole				



REMARKS: Hole terminated at 30.0 ft. due to auger refusal. No water in hole.
D.O. = 2 in. Drive Open Sampler

VERTICAL SCALE: 1 in. to 10 ft. Golder Associates **DRAFT** Sheet 1 of 1

Dwg. No. AB13-1216-002 Date Mar 82 Eng. P.C.

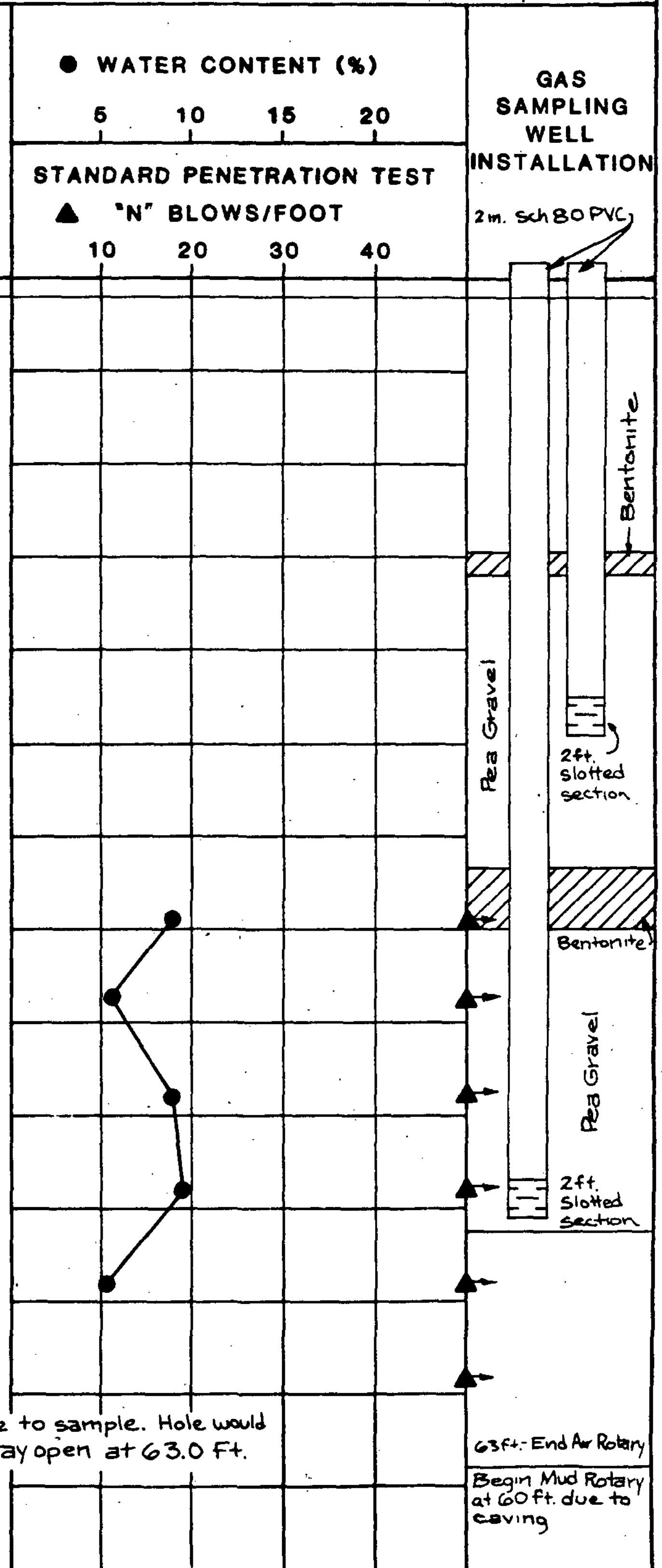
RECORD OF BOREHOLE BH-2A

COORDINATES: N 10,548.86 E 9,083.60

LOCATION: Midway Landfill | DATUM: MSL | DATE: 18 January – 2 February 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. | BORING METHOD: 4 in. I.D. Auger 0-10 ft. 3⅝ in. O.D. air/mud rotarty 10-120 ft.

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT DRILLING TIME (min.)	ELEVATION
374.0 / 0	Very dense, gray, silty, fine to medium SAND, some gravel, trace cobbles, to fine to medium SAND and SILT, some gravel and cobbles					370, 365, 360, 355, 350, 345
			S-1	2" D.O.	50/5"	340
			S-2	2" D.O.	50/5"	335
			S-3	2" D.O.	50/4"	330
326.0 / 48.0	Very dense, gray, fine to medium SAND, trace to some silt and gravel		S-4	2" D.O.	50/6"	325
322.0 / 52.0	Very dense, gray, silty fine to medium SAND, some gravel to silty, fine to medium SAND and GRAVEL		S-5	2" D.O.	84/9"	320
			S-6	2" D.O.	50/3"	315
314.0 / 60	Gray, fine to coarse SAND and fine to coarse GRAVEL with trace to some cobbles and boulders		S-7	2" D.O.		310
			S-8	M.R.	40	
	(Continued on next sheet)		S-9	M.R.	20	



REMARKS: No samples were obtained in BH-2A from 0-30ft. as this information was obtained in BH-2. The hole was augered with a 4 in. I.D. hollow stem auger to 10ft. A 3⅝ in. air rotary bit was used from 10-63 ft. On 1 Feb 82 began drilling with mud rotary at 63ft. On 16 Feb 82 hole caved in at 50ft. and mud drained out of hole. Installed gas sampling wells on 16 Feb 82. D.O. = 2 in. Drive Open Sample M.R. = Mud Rotary Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 2

Dwg. No. A83-1276-012 Date Mar 82 Eng. P.C.

RECORD OF BOREHOLE BH-2A (contd.)

COORDINATES: N 10,548.86 E 9,083.60

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 18 January - 2 February 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 4 in. I.D. Auger 0-10 ft. 3⅝ in. O.D. air/mud rotary 10-120 ft.

SOIL PROFILE		SAMPLES			ELEVATION	● WATER CONTENT (%) 5 10 15 20 / STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/FOOT DRILLING TIME (min.)		
		S-10	M.R.	45	300	
		S-11	M.R.	–	295	
		S-12	M.R.	45	290	
287.0 / 87.0	Yellowish brown, clayey SILT to silty CLAY, trace to some fine to coarse sand and trace fine gravel	S-13	M.R.	45	285	
		S-14	M.R.	30	280	
		S-15	M.R.	15	275	
		S-16	M.R.	30	270	
		S-17	M.R.	35	265	▲ →
		S-18	2" D.O.	3/100		
		S-19	M.R.	15	260	
254.0		S-20	M.R.	15	255	
120.0	End of Hole					

REMARKS: M.R. = Mud Rotary Sample
D.O. = 2 in. Drive Open Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 2 of 2

Dwg. No. A813-1276-015 Date May 82 Eng.

RECORD OF BOREHOLE BH-3

LOCATION: Midway Landfill **DATUM:** MSL

COORDINATES: N 11,268.72 E10,212.33

DATE: 19 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN.

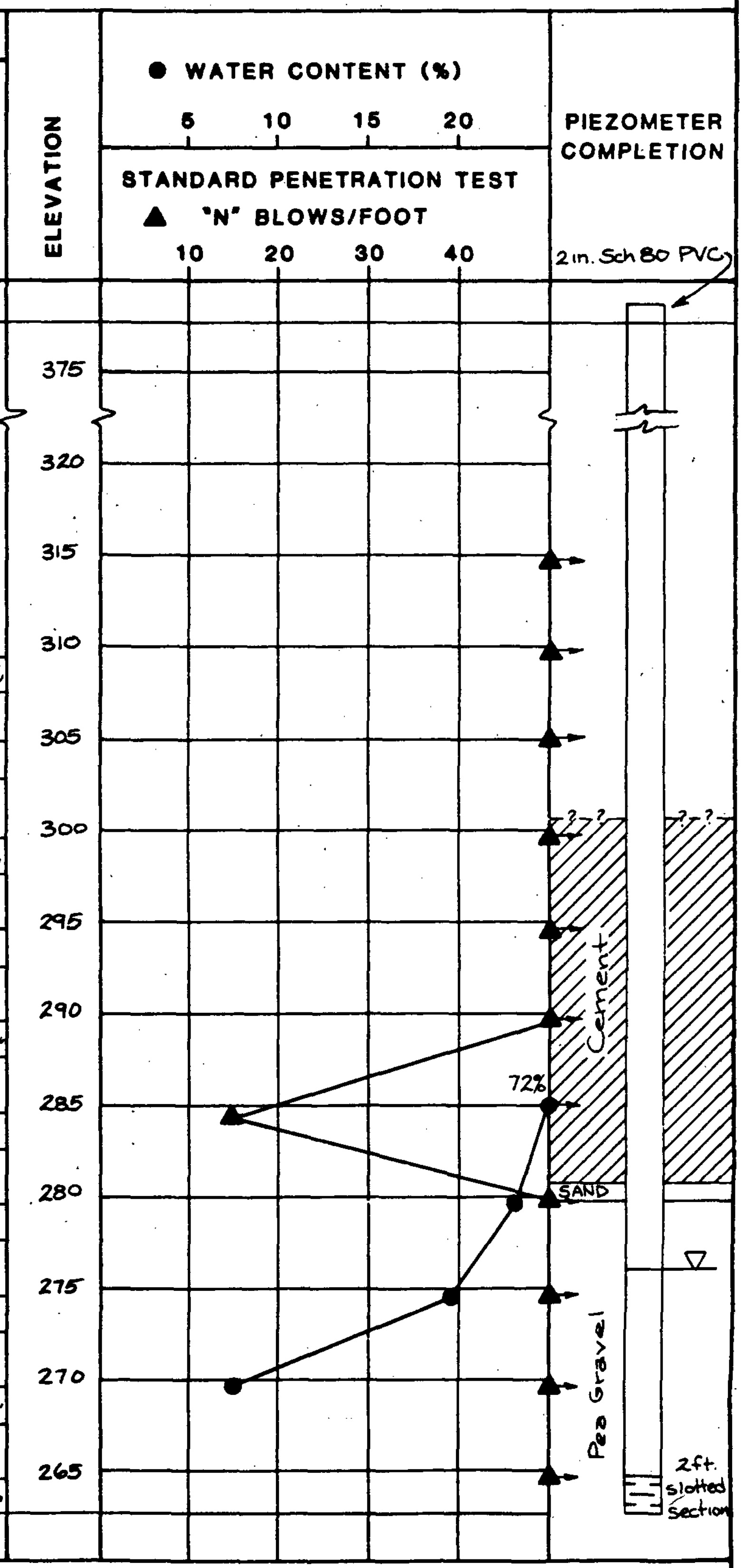
BORING METHOD: 4in. I.D. hollow stem auger

SOIL PROFILE

ELEV. / DEPTH	DESCRIPTION
377.8 / 0	Dark gray to black mixture of decomposed paper, plastic, steel, wood and some soil (Fill)
285.8 / 92.0	
283.8 / 94.0	Stiff, brown and green, silty CLAY, some roots and organics
279.6 / 98.3	Soft, black, ORGANICS & PEAT
275.8 / 102.0	Very dense, brown, medium to coarse silty SAND and CLAY, some gravel
271.8 / 106.0	Very dense, blue-green, clayey fine SAND & SILT, trace-some gravel to clayey SILT & fine SAND, some gravel
262.8 / 115.0	Very dense, green & gray clayey GRAVEL & SAND some cobbles & boulders
	End of Hole

SAMPLES

NUMBER	TYPE	BLOWS/FT.
S-1	2" D.O.	50/1"
S-2	2" D.O.	50/1"
S-3	2" D.O.	50/6"
S-4	2" D.O.	53
S-5	2" D.O.	50/4"
S-6	2" D.O.	14
S-7	2" D.O.	62
S-8	2" D.O.	70
S-9	2" D.O.	50/3"
S-10	2" D.O.	100/2"



REMARKS: Hole terminated at 115.0 ft. due to auger refusal
D.O. = 2 in. Drive Open Sample

▽ Water Level at 276.0 on 9 March 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1

Rev. Dwg. No. A813-1276-003 Date Mar 82 Eng. P.C.

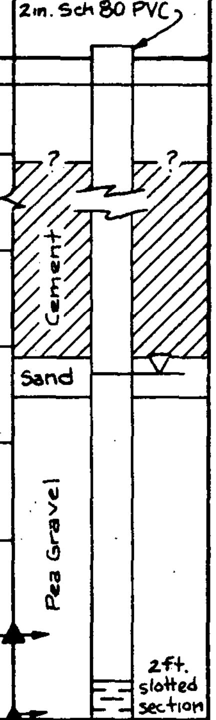
RECORD OF BOREHOLE BH-4

COORDINATES: N 11,227.58 E 10,206.00

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 20 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 4in. I.D. hollow stem auger

SOIL PROFILE			SAMPLES				● WATER CONTENT (%) 5 10 15 20 / STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40	PIEZOMETER COMPLETION
ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION		
378.7 / 0	Dark gray to black mixture of decomposed paper, plastic, steel, wood and some soil (Fill)					375		
						320		
						315		
						310		
						305		
			S-1	2" D.O.	50/6"	300		
295.7			S-2	2" D.O.	50/6"			
83.0	End of Hole							



REMARKS: D.O. = 2 in. Drive Open Sample

Water Level at 313.4 ft. on 9 March 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT**

Sheet 1 of 1

Dwg. No. A813-1276-004 Date Mar 82 Eng. P.C.

RECORD OF BOREHOLE BH-5

COORDINATES: N 10,735.93 E 10,118.39

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 21 January 1982

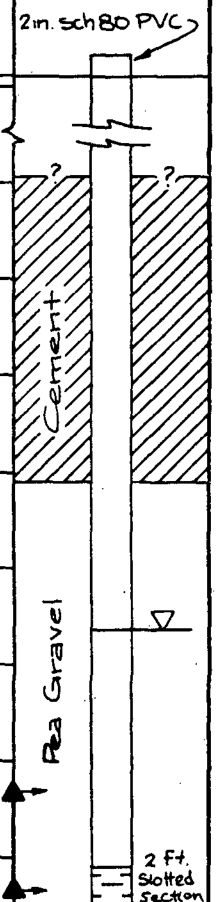
SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 4 in. I.D. hollow stem auger

ELEV. / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT. PLOT	NUMBER (SAMPLES)	TYPE (SAMPLES)	BLOWS/FT. (SAMPLES)	ELEVATION
395.3 / 0	Dark gray to black, mixture of decomposed paper, plastic, steel, wood and some soil (Fill)					395, 340, 335, 330, 325, 320, 315, 310
			S-1	2" D.O.	100/4"	
						305
302.3			S-2	2" D.O.	50/3"	
93.0	End of Hole					

● WATER CONTENT (%): 5, 10, 15, 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT: 10, 20, 30, 40

PIEZOMETER COMPLETION



REMARKS: D.O. = 2in. Drive Open Sample

▽ Water Level at 316.9 ft. on 9 March 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1

Rev. ___ Dwg. No. A813-1276-005 Date Mar 82 Eng. P.C.

RECORD OF BOREHOLE BH-6

COORDINATES: N10,041.56 E 9,599.81

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 9-10 February 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** Air Rotery - Drill and Drive

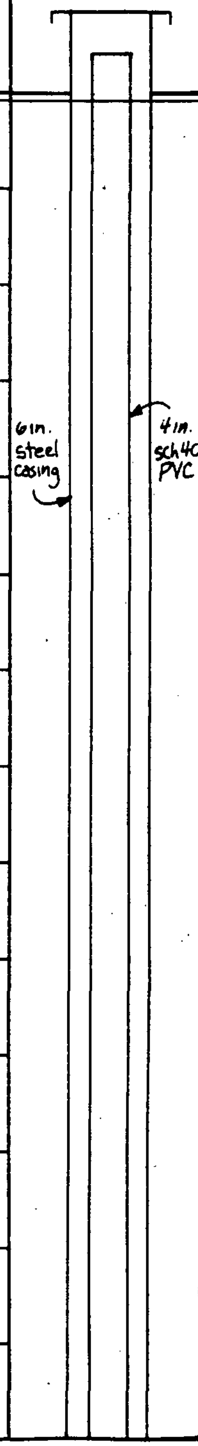
ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION
384.5					
0	Light to medium brownish-gray, fine to coarse gravelly fine to coarse SAND to fine to coarse sandy fine to coarse GRAVEL, trace to some silt, cobbles and boulders	S-1	A.R.	4	
					380
		S-2	A.R.	5	
					375
		S-3	A.R.	5	
					370
		S-4	A.R.	5	
					365
		S-5	A.R.	3	
					360
		S-6	A.R.	4	
					355
		S-7	A.R.	4	
					350
		S-8	A.R.	4	
					345
		S-9	A.R.	4	
					340
		S-10	A.R.	4	
					335
		S-11	A.R.	6	
					330
		S-12	A.R.	10	
					325
		S-14	A.R.	5	
					320
		S-15	A.R.	8	

SOIL PROFILE — STRAT. PLOT — SAMPLES

● WATER CONTENT (%) 5 10 15 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40

PIEZOMETER COMPLETION



(Continued on Next Sheet)

REMARKS: A.R. = Air Rotary Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT**

Dwg. No. AB13-1276-006 Date Mar 82 Eng. P.C.

RECORD OF BOREHOLE BH-6 (contd.)

COORDINATES: N 10,041.56 E 9,599.81

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 9-10 February 1982

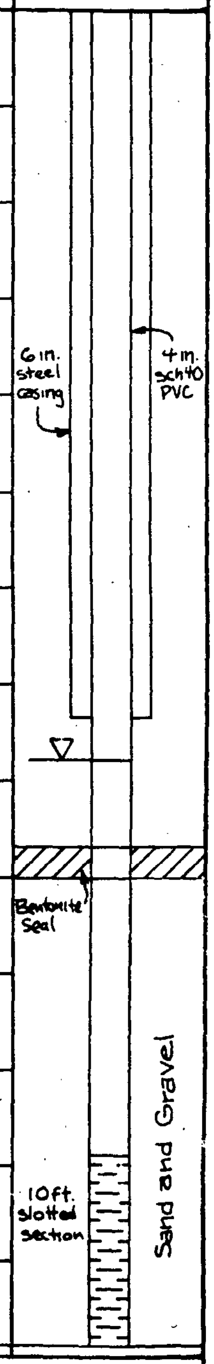
SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** Air Rotary - Drill and Drive

ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION
		S-15	A.R.	15	
					310
		S-16	A.R.	15	
					305
		S-17	A.R.	8	
					300
294.5		S-18	A.R.	10	
90.0					295
	Light to medium brownish-gray, fine to coarse gravelly fine to coarse SAND to fine to coarse GRAVEL, trace to some silt, cobbles and boulders	S-19	A.R.	10	
					290
		S-20	A.R.	20	
					285
		S-21	A.R.	10	
					280
		S-22	A.R.	15	
					275
		S-23	A.R.	15	
					270
		S-24	A.R.	10	
					265
		S-25	A.R.	8	
					260
		S-26	A.R.	10	
					255
		S-27	A.R.	12	
					250
		S-28	A.R.	15	
245.5 / 139.0	End of Hole				

● WATER CONTENT (%) 5 10 15 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40

PIEZOMETER COMPLETION



REMARKS: A.R. = Air Rotary

∇ Water Level at 274.0 ft. on 9 March 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 2 of 2

Rev. ____ Dwg. No. A813-1276-007 Date Mar 82 Eng. P.C.

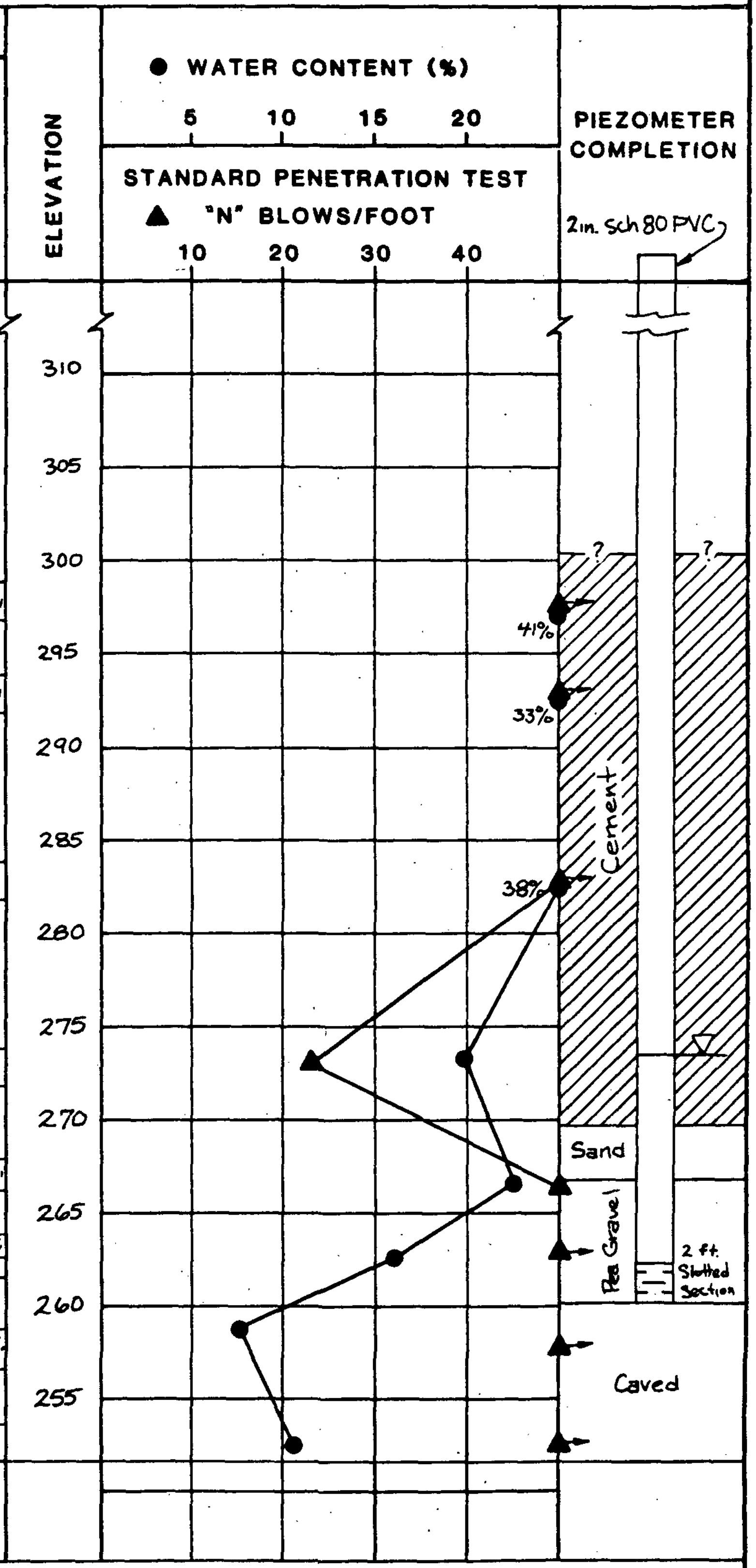
RECORD OF BOREHOLE BH-7

COORDINATES: N10,736.54 E10,099.50

LOCATION: Midway Landfill   DATUM: MSL   DATE: 10-15 February 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN.   BORING METHOD: 4in. I.D. hollow stem auger

ELEV. DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	BLOWS/FT.
394.9 / 0	Dark gray to black, mixture of decomposed paper, steel, wood and some soil (Fill)	S-1	2" D.O.	50/4"
		S-2	2" D.O.	55/6"
		S-3	2" D.O.	70
272.9 / 122.0	Soft, blue & gray, silty CLAY			
271.4 / 123.5	Loose to compact, blue, coarse to fine SAND to SAND and SILT	S-4	2" D.O.	23
270.9 / 124.0	Compact, mottled brown, tan & gray SILT, some fine sand, trace clay to SILT and fine SAND	S-5	2" D.O.	50/3"
264.9 / 130.0	Very dense, blue-gray, silty coarse to fine SAND, some gravel to sandy SILT some gravel	S-6	2" D.O.	100/2"
		S-7	D+M	
258.9 / 136.0	Very dense, gray, coarse to fine GRAVEL, trace to some sand	S-8	D+M	100/55"
		S-9	D+M	100/3"
251.9 / 143.0	End of Hole			



REMARKS: Hole terminated at 143.0 due to auger refusal
D+M = 2 3/8 in. I.D; 3 1/4 in. O.D. drive sampler
Sampler driven with 300lbs., 30 in. drop
D.O. = 2 in. Drive Open Sample

▽ Water Level at 276.2 on 9 March 82

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates   DRAFT   Sheet 1 of 1

Rev. Dwg. No. A813-1276-008 Date Mar 82 Eng. D.C.

RECORD OF BOREHOLE BH-8

COORDINATES: N 11,001.55 E 9,180.17

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 11-12 February 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** Air Rotary - Drill and Drive

SOIL PROFILE			SAMPLES				WATER CONTENT (%) 5 10 15 20 / STANDARD PENETRATION TEST "N" BLOWS/FOOT 10 20 30 40	PIEZOMETER COMPLETION
ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION		
361.8 / 0	Light to medium grayish-brown, fine to coarse gravelly, fine to coarse SAND to fine to coarse sandy, fine to coarse GRAVEL, trace to some silt, cobbles and boulders		S-1	A.R.	5	360		
			S-2	A.R.	3	355		
			S-3	A.R.	2	350		
			S-4	A.R.	5	345		
			S-5	A.R.	5	340		4 in. Sch 40 PVC
			S-6	A.R.	-	335		6 in. Steel casing
			S-7	A.R.	5	330		
			S-8	A.R.	8	325		
			S-9	A.R.	5	320		
			S-10	A.R.	8	315		
			S-11	A.R.	5	310		
			S-12	A.R.	10	305		
			S-13	A.R.	10	300		

(Continued on Next Sheet)

REMARKS: A.R. = Air Rotary Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT**

Dwg. No. A813-1276-009 Date Mar-82 Eng. P.C.

RECORD OF BOREHOLE BH-8 (contd.)

LOCATION: Midway Landfill **DATUM:** MSL

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN.

COORDINATES: N 11,001.55 E 9,180.17

DATE: 11-12 February 1982

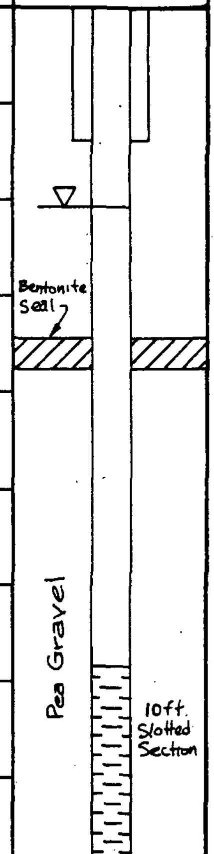
BORING METHOD: Air Rotary - Drill and Drive

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	DRILLING TIME (minutes)	ELEVATION
		S-14	A.R.	10	
		S-15	A.R.	10	290
		S-16	A.R.	10	285
		S-17	A.R.	10	280
271.8		S-18	A.R.	10	275
90	Bluish gray, fine to coarse GRAVEL, some fine to coarse sand, some silt	S-19	A.R.	10	270
		S-20	A.R.	10	265
		S-21	A.R.	10	260
250.8		S-22	A.R.	10	255
111.0	End of Hole				

● WATER CONTENT (%) 5 10 15 20

STANDARD PENETRATION TEST ▲ "N" BLOWS/FOOT 10 20 30 40

PIEZOMETER COMPLETION



REMARKS: A.R. = Air Rotary

▽ Water Level at 286.8 ft. on 9 March 1981

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 2 of 2

Rev. Dwg. No. A813-1216-010 Date Mar 82 Eng. P.C.

APPENDIX C

FIELD DATA

- o Field Water Quality Analyses
- o Methane Gas Levels
- o Water Level Measurements
- o Topographic Survey Results

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PART I - MIDWAY LANDFILL

DRAFT

Table C-1
Results of Field Water Quality Analyses-Midway Landfill
(Conducted February 22, 1982)

Location	Depth (ft)	Temp(1) °C	Salinity PPT	Conductivity µmhos/cm	pH (2)
BH-3	100.5	10	1.0	1230	8.70
BH-4	66.7	12	4.0	5000	8.25
BH-5	77.1	10	7.8	9500	8.45
BH-7	118.5	13	2.0	2875	7.80
BH-6	110.4	10	2.75	3650	6.75
BH-8	79.5	11	0.75	1250	6.75
Pond near Quonset Hut	Surface	4	0	482	6.25
South Pond (SW corner)	Surface	3.5	0	500	5.90
East Corner of North Pond	Surface	2.5	0	187	5.80
West Corner North Pond	Surface	5	0	209	6.10

(1) Measured with a YSI Model 33 meter
(2) Measured with a Fisher Model 107 Digital meter

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Table C-2
Methane Gas Readings - Midway Landfill
in Percent Natural Gas

Gas Monitoring Well Number(1)	Date 12/15/81(2)	12/22/81(2)	1/7/82(2)	1/12/82(3)	2/23/82(3)
1	-	0	<0.4	0	0
2	-	6	32	17	0.8
3	-	0	<0.4	0	0
4	9	<0.4	<0.4	1.2	0
5	7	6	25	5	40
6	-	0	<0.4	0	0
7	8	0.8	0.8	0	0
8	<0.4	0	<0.4	0	0
9	<0.4	0	0	0	0
10	10	12	4	0.8	0
11	0	0	<0.4	0	0
12	-	0	<0.4	0	0
13	53	50	56	65	60
14	18	35	55	20	35
15	-	20	38	20	5
16	45	50	60	3	13
17	46	43	36	0	55
18	<0.4	Trace	<0.4	0	0
19	<0.4	0	<0.4	0	<0.4

(1) Locations are shown on Figure 2-1.

(2) Measured with a Bacharach Model H Gas Tester with a downhole probe, by Health Department

(3) Measured with a Bacharach Model H Gas Tester without a downhole probe, by Golder Associates

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HDP
RPL
SSF

Seattle-King County / DEPARTMENT OF PUBLIC HEALTH

400 Yesler Way   Seattle, Washington 98104   (206) 625-2161

ROUTING	DATE	INITIAL
ACTION		
AEM	RPL	
FILE		
INFORMATION		

81 DEC 2 PM 2:02

December 1, 1981

JESSE W. TAPP, M.D., M.P.H.
Director of Public Health

cc
+
alt

Eugene Avery, Director
Seattle Engineering Department
910 Municipal Building

Dear Mr. Avery:

We have just completed our initial methane gas migration study of the Midway landfill site. Methane gas readings were taken from test holes, building air spaces, storm drains, and Pacific Northwest Bell vaults in pertinent locations around the perimeter of the landfill. The study was carried out on four separate days between 11/5/81 - 11/20/81.

Our findings show evidence that methane gas is migrating off-site at varying locations along the west side. To date, the positive readings have only been found in test holes, storm drains and PNB vaults. All of the building structures sampled were absent of gas.

Multiple readings were taken over the four days at many of our monitoring locations on the west perimeter that initially showed a methane level of 0.4% in total gas on the first day (11/5/81). (We have included a map and summary of findings that provides more detailed information of our study for your review.)

On November 18, Washington Natural Gas representatives were asked to test samples of gas from a number of locations on the west border revealing positive readings on our test equipment. The purpose of the WNG testing was to insure that the concentrations of gas we were picking up were not from leak(s) in WNG gas lines located in the vicinity. The lab analysis on these samples confirmed that the levels found were not associated with WNG.

Although our initial study did not uncover any "imminent" hazard conditions (e.g. explosive concentrations of gas) in the building structures tested, the existence of methane gas migrating laterally off-site certainly establishes a potential safety/fire hazard condition. We would like to meet with you at your earliest convenience to discuss corrective action your Department must take to eliminate this problem. Until then, if you have any questions or would like additional information, please call me or Wally Swofford at 625-2125.

Sincerely,

John P. Nordin

John P. Nordin, Chief
Environmental Health Services

cc: Bob McCormick
Avery Wells
Larry Kirchner
Dr. Tapp

JPN:wsg

DRAFT

SUMMARY OF FINDINGS
METHANE GAS MIGRATION STUDY
- Midway Landfill -

Seattle-King County Health Department staff monitored for methane gas at various locations around the perimeter of the Midway landfill site on November 5, 12, 18, and 20. The test equipment measured for the presence of methane gas in samples of air aspirated from test holes made by a bar hole punch, building structure air spaces (interior-crawl spaces, etc.), storm drains, and Pacific Northwest Bell ground vaults.

Methane gas forms potentially explosive mixtures with air in concentrations between 4%-15% total gas-in-air. Our field test equipment measures the gas on two scales:

1. Percent of methane gas as related to only the lower explosive limit (LEL) of 4%.
   (Readings from 0.0-1.0, with 1.00 representing the LEL of 4%), and
2. Total percent of methane gas in air
   (Readings from 0.00-100%)

In this study, the Health Department considered any concentration of gas greater than 0.1 of the LEL (or 0.4% total gas in air) as significant and categorized it accordingly. For purposes of clarity, the following table of gas concentrations that reference sample locations A-P on the map are expressed in levels of methane gas greater than 0.4% total gas in air:

DATE - CONCENTRATION

LOCATION	November 5th	November 12th	November 18th	November 20th
A. (Barhole)				7.0%
B. (Barhole)				45.0%
C. (Barhole)				33.0%
D. (Barhole)	12.0%			
E. (Barhole)	5.0%	15.0%	30.0%	
F. (Barhole)	5.0%		0.0%	
G. (PNB Vaults)	0.2%			0.6%
H. (PNB Vaults)		0.0%		0.6%
I. (PNB Vaults)		0.0%		0.5%
J. (PNB Vaults)		0.0%	0.0%	2.2%
K. (Barhole)	1.6%			
L. (Barhole)	35.0%		7.0%	
M.				0.4%
N. (Barhole)	5.0%		0.0%	
O. (PNB Vaults)	1.8%		0.0%	3.72%
P. (Storm Drains)	2.1%		0.0%	0.4%

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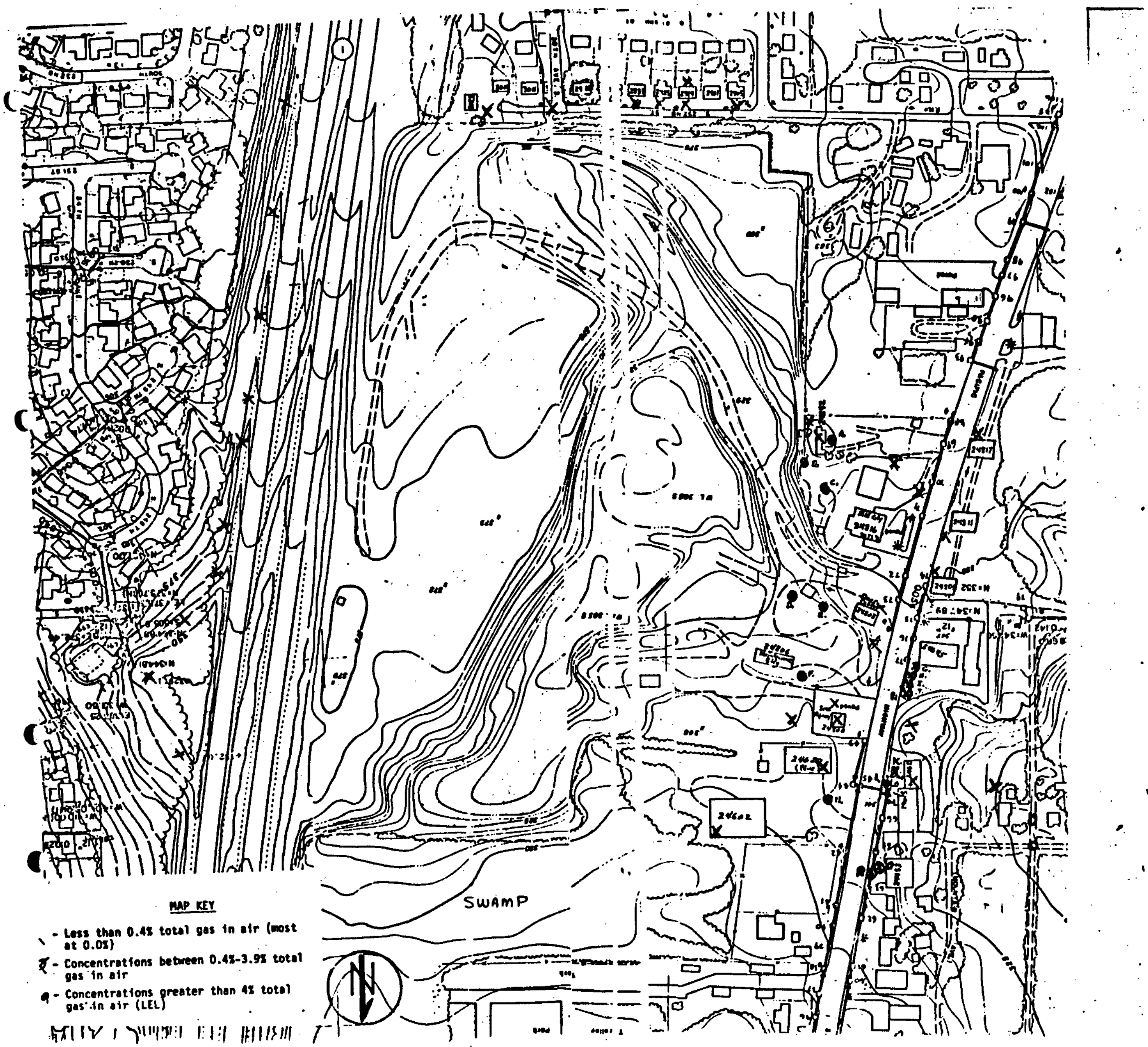
SWAMP
MAP KEY
- Less than 0.4% total gas in air (most at 0.0%)
- Concentrations between 0.4%-3.9% total gas in air
- Concentrations greater than 4% total gas in air (LEL)

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TABLE C-3

WATER LEVEL MEASUREMENTS - MIDWAY LANDFILL

Well Number	Ground Surface Elevation (ft)	READINGS (DEPTH BELOW GROUND SURFACE - FT)															
		1/20/82	1/21/82	1/22/82	1/27/82	1/29/82	2/1/82	2/2/82	2/3/82	2/8/82	2/10/82	2/11/82	2/15/82	2/22/82	2/23/82	3/9/82	4/7/82
BH-1B	333.1						28.0	44.3	46.7	48.3	48.2		46.5		43.9	40.2	45.7
BH-2A	374.0												B&D @50.0				
BH-3	377.8	47.5	84.7	101.8	105.7	105.8				106.9			103.0	100.5	105.4	101.9	107.1
BH-4	378.7			67.1	67.0	67.5				66.9			66.0	66.7	66.7	65.4	65.9
BH-5	395.3				77.5	77.7				77.5			77.0	77.1	79.2	78.5	78.5
BH-6	384.5										112.0	112.5	112.0	110.4	110.2	110.4	113.6
BH-7	394.9												122.0	118.5	119.6	118.7	121.8
BH-8	361.8												83.0	79.5	78.5	75.1	79.3
Piez A	344.8															11.1	9.8
Piez B	358.6															21.9	-
Linda Heights																	163.4

1. All readings made, using an electric well sounder
2. B & D = Block and Dry

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PART II - KENT HIGHLANDS LANDFILL

Table C-4
Results of Topographic Survey
Performed by City of Seattle Engineering Department

Location	Coordinates North	Coordinates East	Ground Surface Elevation ft. (MSL)
BH-1	11,551.24	9,147.62	333.5
BH-1B	11,545.03	9,154.61	333.1
BH-2A	10,548.86	9,083.60	374.0
BH-3	11,268.72	10,212.33	377.8
BH-4	11,227.58	10,206.00	378.6
BH-5	10,735.93	10,118.39	395.3
BH-6	10,041.56	9,599.81	384.5
BH-7	10,736.54	10,099.50	394.9
BH-8	11,001.55	9,180.17	361.8
Piez-A	11,585.05	9,454.53	344.8
Piez-B	11,488.02	9,867.96	358.6
Pond along north side of landfill	-	-	340.0
Pond near storage hut-west side	-	-	327.8
Pond in SW corner of landfill	-	-	336.2
Linda Heights Well	11,517.82	11,028.33	354.8
Catch Basin east of I-5	11,470.55	10.918.59	328.8

Table C-5

Results of Field Water Quality Analyses - Kent Highlands Site

Location	Depth (ft)	Temp(1) °C	Salinity PPT	Conductivity μmhos
MW 1 Upper	18.0	11.0	0.2	240
Middle	28.5	9.5	0.2	142
Lower	39.3	11.0	0.1	130
MW 2 Upper	12.7	8.0	1.0	900
Middle	26.5	8.5	0.2	240
Lower	41.8	8.5	0.2	155
MW 3 Upper	17.0	8.0	0.9	700
Middle	27.5	8.0	0.3	290
Lower	42.0	8.0	0.1	130
MW 4 Upper	15.3	5.0	0.25	610
Middle	24.5	5.0	0.25	370
Lower	41.5	8.0	0.1	110
MW 5 Upper	18.0	9.7	1.0	920
Middle	26.5	10.0	0.5	600
Lower	40.0	10.0	0.1	170
TW2	160.0	12.0	0.0	110
Surface Pond at South End of Toe Drain (2)	Surface	12.0	3.0	3300
Settlement Pond East of Landfill Toe:				
South End (2)	Surface	5.0	0.5	390
North End	Surface	4.0	0.35	370
Small Surface Water Pond between MW1 and MW2 (2)	Surface	5.0	0.4	285
Treatment Pond	Surface	11.5	1.5	1850
Inlets to Treatment Pond:				
Spring Drains	Surface	11.0	0.4	600-700
Old Leachate Collector	Surface	19.0	1.25	2200
Toe Drains	Surface	15.0	2.0	4000
Small Surface Water Pond between MW1 and MW5 (2)	Surface	6.0	0.4	250-300
Settlement Pond at NW Corner of Site Along Entrance Road (2)	Surface	6.5	0.75	625
Upper Settlement Pond:				
Inlet (2)	Surface	5.0	1.5	1200-1400
Outlet (2)	Surface	5.0	0.8	600-700
Inlet of Suface Water into Unnamed Creek (2)	Surface	6.5	0.75	600
Northside of Bridge - Unnamed Creek (2)	Surface	4.0	0	60
150 ft Upstream of Unnamed Creek in Green River (2)	Surface	4.0	0	60
150 ft Downstream of Unnamed Creek in Green River (2)	Surface	4.0	0.3	50

(1) Measured with a YSI Model 33 meter

(2) Note: Measurements taken after period of heavy rains, Green River near flood stage.

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Table C-6
Methane Gas Readings - Kent Highlands Landfill

Location	Date	Reading % Natural Gas (1)
PZ-2 Deep	1/28/82	0.5
Shallow	1/28/82	50
PZ-3 Deep	1/28/82	0.8
Shallow	1/28/82	0.0
PZ-5	1/28/82	0.0
PZ-4 Deep	1/28/82	0.0
TW 2	1/28/82	0.0
TH 4	1/28/82	0.0
TH 1	1/28/82	0.0
MW 1	1/28/82	0.0
MW 2	1/28/82	0.0
MW 3	1/28/82	0.0
MW 4	1/28/82	0.0
MW 5	1/28/82	0.0

(1) Measured with a Bacharach Model H gas tester without a downhole probe by Golder Associates.

Table C-7
Water Level Measurements - Kent Highlands Landfill

Well Number	Ground Surface Elevation (ft)	Depth to Open Interval (ft)	Readings (1) (Depth Below Ground Surface - ft) 1/27/82	3/5/82	3/8/82	4/8/82
MW-1a	43.6	18.0	2.1	2.9		
b		28.5	2.8	2.2		
c		39.3	1.6	1.9		
MW-2a	41.3	12.7	2.0	1.6		
b		26.5	1.8	2.0		
c		41.8	3.1	4.7		
MW-3a	40.5	17.0	6.4	4.3		
b		27.5	2.2	2.9		
c		42.0	2.5	6.5		
MW-4a	36.1	15.3	4.5	5.6		
b		24.5	4.75	9.1		
c		41.5	4.7	9.6		
MW-5a	36.6	18.0	6.4	10.9		
b		26.5	6.4	12.3		
c		40.0	6.15	12.4		
TW 2	274.0	210	142.0			142.0
TW 3	305.0	261				
PZ-2a	305.3	285	152.0			
b	305.3	123	108.0			
PZ-3a	299.3	239			103.3	
b	287.5	177			105.3	
PZ-4a	274.7	195	36.5			
PZ-5	270.6	196	46.0			
PZ-6	268.7	226				
TH-1	282.6	224.5	155.0			
TH-4	259.8	220.5	154.0			153.9
PT-3	278.0	288.0	B&D @ 136(2)			

(1) All readings made using an electric well sounder.
(2) B&D = Blocked and Dry

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Table C-8
Results of Topographic Survey
Performed by City of Seattle Engineering Department

Location	Coordinates North	Coordinates East	Ground Surface Elevation (ft)
MW-1	145,840	1,643,110	43.6
MW-2	145,690	1,643.120	41.3
MW-3	145,540	1,643,100	40.5
MW-4	145,615	1,643,260	36.1
MW-5	145,750	1,643,480	36.6
TW-2	146,912	1,642,022	259.8
TW-3	147,046	1,640,386	305.0
PZ-2 a & b	147,037	1,640,378	305.3
PZ-3 a & b	146,767	1,640,395	287.5
PZ-4	146,112	1,640,458	274.7
PZ-5	146,388	1,640,633	275.5
PZ-6	146,879	1,641,012	268.7
TH-1	147,010	1,641,498	282.9
TH-4	147,018	1,641,889	274.0
PT-3	147,005	1,641,403	278.0
Settlement Pond Below Tow Buttress			30.4
Treatment Pond			33.1
Unnamed Creek - South Side of Bridge			19.2
Green River at Inlet of Unnamed Creek			18.3

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APPENDIX D

COVER MATERIAL SEARCH

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An investigative program was undertaken to determine potential sources of fine-grained material which could be used separately or combined with other near-site materials to form a suitable final cover. The following is a list of city, county, and state offices that were contacted concerning possible public or private sources of cover material.

City

- o City Building Department - Permits
- o City Building Department - Environmental
- o City Building Department - Construction and Land Use
  - Mr. Bernell
- o Metro - Metro Tunnel Project
  - Dick Sandis

County

- o King County - Permits for Filling and Grading
  - Mark Mitchell

State

- o Department of Natural Resources
  - Joe Henry, District Conservationist
  - Don Theo, Surface Mining
- o Department of Transportation - District Office
  - George Leary

Mr. Bernell from the City Building Department - Construction and land use was contacted concerning sources of final cover material within the City limits. His office reviews all grading and excavation permits before they are issued. These permits are listed in the Seattle Daily Business Journal. Review of these permits on a regular basis could indicate potential sources of fine grained material that could be used for a final cover. Material that is excavated within the city must be disposed of immediately and thus if material was found it would have to be stockpiled or placed directly on the landfill.

Dick Sandis from METRO was contacted concerning the material to be excavated for the metro tunnel. It is expected that material from the excavation will be available in early 1984. We requested copies of the boring logs for exploratory holes being made for the tunnel. Lynn Wilcox, project manager for the METRO tunnel, will contact Golder Associate when the boring results become available. At that time we will review them to determine the suitability of the material for a final soil cover.

Mark Mitchell from King County - Permits for Filling and Grading was contacted concerning sources of final cover material within King County. His office issues permits for filling and grading within the county. Again material is occassionally available but only on short notice and for short periods of time. He suggested that he could be of help in locating material if the city was prepared to obtain it.

Joe Henry and Don Theo from the Department of Natural Resources were contacted. Their office sent a list of all the surface mining activities in south King County. These are licensed mining opertions (predominantly sand and gravel pits). Mr. Theo mentioned a few operations, in particular that might have some

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fine-grained material but upon contacting it was learned that they contained predominantly sand and gravel also.

George Leary from the Washington State Department of Transportation District office was contacted concerning the Mt. Baker tunnel excavation. He will contact Golder Associates or the City of Seattle if material is available from this project.

APPENDIX E

HYDROLOGIC ANALYSIS

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HYDROLOGIC ANALYSIS

Water Balance for Cover Material

A water balance to estimate potential infiltration through the cover was calculated using the Thornthwaite method as recommended by the EPA (Lutton, et al., 1979). Climatic data for the Seattle-Tacoma airport, taken from Snyder, et al., (1973) was used in the water balance. The Seattle-Tacoma airport is the closest climatological station for which appropriate precipitation and evapotranspiration data are available and is considered representative of the Midway site.

The water balance methodology is illustrated in Table E-1. Monthly values of precipitation, evapotranspiration and surface runoff are listed. Precipitation and evapotranspiration are from the Seattle-Tacoma airport station and surface runoff is based upon runoff factors for King County, given in Storm Drainage Control-Requirements and Guidelines for King County (1979). Soil moisture storage, equivalent to 6.0 inches of water, was derived from data in Lutton, et al. (1979) based upon anticipated cover characteristics.

The water balance indicates that of the annual 33.8 inches of precipitation, 8.4 inches is lost as surface runoff, 18.5 inches is lost as evapotranspiration, and 6.9 is available for infiltration through the cover. Available infiltration occurs only during the three-month period of January through March.

The actual infiltration through the cover will probably be limited by the permeability of the cover rather than the total water available. Using Darcy's equation,

$$q = Ki$$

Table E-1
Monthly Water Balance Analysis in Inches
Using the Thornthwaite Method

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
Precipation (P)	4.7	4.0	3.4	2.1	1.6	1.3	0.6	0.9	1.7	3.3	4.5	5.7	33.8
Surface Runoff (R.O.)	1.2	1.0	0.9	0.5	0.4	0.3	0.2	0.2	0.4	0.8	1.1	1.4	8.4
Available Moisture (I)	3.5	3.0	2.5	1.6	1.2	1.0	0.4	0.7	1.3	2.5	3.4	4.3	25.4
Potential Evapotranspiration (PET)	0.3	0.6	1.2	1.8	3.1	3.8	4.5	4.1	2.8	1.8	0.8	0.5	25.3
I-PET	3.2	2.4	1.3	-0.2	-1.9	-2.8	-4.1	-3.4	-1.5	+0.7	+2.6	+3.8	
Soil Moisture Storage (ST)	6.0	6.0	6.0	5.8	3.9	1.1	0	0	0	0.7	3.3	6.0	
Change in ST	0	0	0	-0.2	-1.9	-2.8	-1.1	0	0	+0.7	+2.6	+2.7	
Actual Evapotranspiration	0.3	0.6	1.2	1.8	3.1	3.8	1.5	0.7	1.3	1.8	0.8	1.6	18.5
Available Infiltration	3.2	2.4	1.3	-	-	-	-	-	-	-	-	-	6.9
Actual Infiltration (Assume K of cover = 10^{-6} cm/sec)	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	3.0
Actual Infiltration (Assuming K of cover = 10^{-7} cm/sec)	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	0.3

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where q = flow rate per unit cover area
K = permeability of cover
i = gradient through cover (assumed equal to 1.0)

the actual infiltration through the cover as a function of cover permeability was calculated. The resulting flows are:

Cover Permeability (cm/sec)	Infiltration Through Cover (in/yr)
3×10^{-6}	6.9
1×10^{-6}	3.0
1×10^{-7}	0.3

As shown above, for cover permeabilities less than 3×10^{-6} cm/sec, the infiltration through the cover will be less than the 6.9 inches of water available. Water not infiltrating will probably appear as seeps on the cover and flow off the site as surface water.

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APPENDIX F

INTERIM GAS INTERCEPTOR TRENCH - MIDWAY

Our Ref: E/82/628

TO: R. BELUCHE

FROM: P. CORSER / J. ROWE

RE: GAS COLLECTION TRENCH

DATE: MARCH 3, 1982

On December 1981 we received a copy of a letter from John P. Nordin, Department of Public Health to Eugene Avery, Seattle Engineering Department dated December 1, 1981, discussing the problem of gas migration at the Midway landfill. The results of gas monitoring in a system of shallow well points placed by the Health Department, along the west side of the fill were presented in the letter. Additional readings of all gas monitoring wells were taken on January 12, 1982 and February 22, 1982 by Golder Associates using a Bacharach Model H Gas Detector.

Upon reviewing the results of monitoring by the Health Department and Golder Associates it appears that there are two localized areas, A and B (see Figure 1), in which high (greater than 0.4%) readings of methane are found. The methane is believed to be migrating to the west from the landfill through pervious pockets and/or lenses within the glacial outwash material surrounding the landfill. In the vicinity of the scale house, to the west of the landfill, a large portion of the area is covered with an impermeable cap of concrete or asphalt which will not allow gas to vent at the surface. Instead we believe it likely that gas migrates to the west underneath the concrete and asphalt. Once reaching Highway 99 it probably travels north through pervious backfill material in utility trenches, thus accounting for the area of high readings found north of the scale house and west of Highway 99 (Area B).

Data indicate that gas is migrating to the west directly underneath the concrete and asphalt covering the area where high concentrations were measured. To date we have no evidence of any deep gas migration but we are currently investigating this possibility by monitoring deep gas wells. Based upon observed conditions we recommend that the gas be intercepted by a gas collection trench. This trench would be located along the west side of the fill as shown in Figure 1. Details of the trench design are shown in Figure 2 and listed below:

- o The exact location of the trench should be determined in the field, adhering to the requirement that no fill should be west of the centerline of the trench.
- o The trench should extend as far south as necessary so that the excavation does not encounter any fill.

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- The trench should be approximately 15 deep throughout it's entire length and a minimum of 2 feet wide at the base. Excavation requirements will dictate the width of the opening at the top. The base of the trench should be sloped a minimum of ½% towards the water collection wells.

- The trench should be backfilled with washed river gravels (1/4 - 3 inch) to within approximately 2 feet of the ground surface. In areas where the trench intersects haul roads the gravel should be compacted before placement of the gas collection pipe or cover materials. A typical cross-section through the trench is shown in Figure 2.

- An 8-inch diameter ADS currugated, perforated, flexible polyethylene drain tubing should be placed on top the gravel backfill. This will serve as a gas collection pipe. In areas where the trench intersects haul roads the polyethylene pipe should be placed inside of a perforated corrugated metal pipe.

- Pea gravel should be compacted around the entire height of the pipe.

- A cover of low permeability material, such as asphalt or low permeability soil should be placed and compacted over the pipe.

- Gas burners should be connected to the gas collection pipe at the two high points along the center-line on the trench. For approximate locations see Figure 1.

- A 4-inch diameter plastic well screen should be placed at the bottom of the gas collection trench at two locations as shown on Figure 1. These will be used to collect water that may accumulate at the base of the trench. Details of these sump wells are shown in Figure 2.

- Sump wells should be pumped if static water levels fill more than 10 feet of the well. If leachate is detected within the wells they should be kept dry to prevent leachate migration to the west.

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It is important to understand that the proposed gas collection trench is a interim solution designed to reduce gas migration into populated areas west of the landfill, as fast and as economical as possible. Although it may be possible to include this interim system as part of the final gas collection system, substantial changes or improvements may be required.

We would be interested in discussing these recommendations with you during our scheduled meeting on March 3, 1982.

Very truly yours,

GOLDER ASSOCIATES

Patrick G. Corser

Jerry Rowe

PGC:JR/bsb
813-1276

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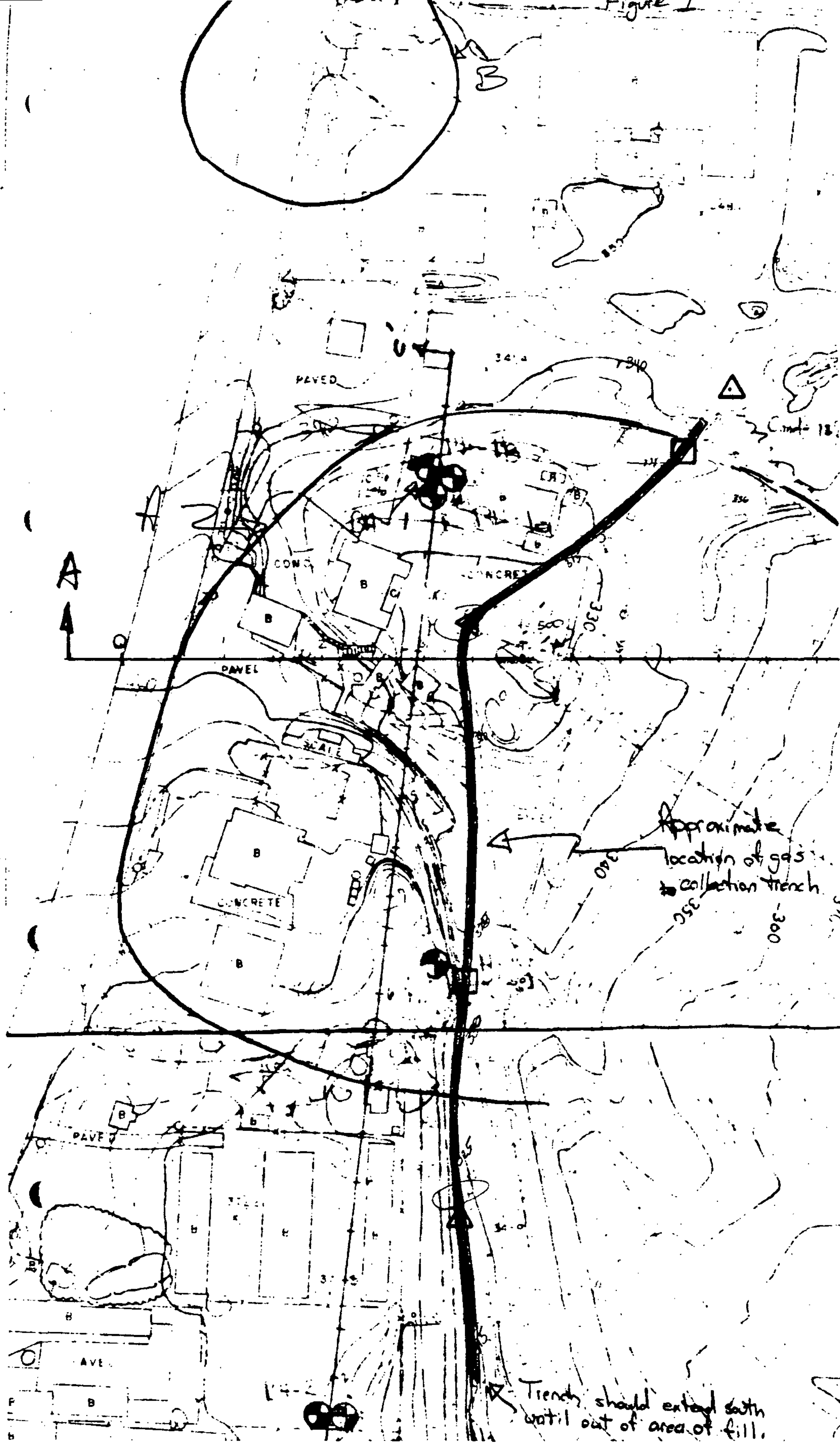

Legend

△ Approximate location of sump wells

☐ Approximate location of gas burners

Midway landfill
313-1296
26 Feb 82

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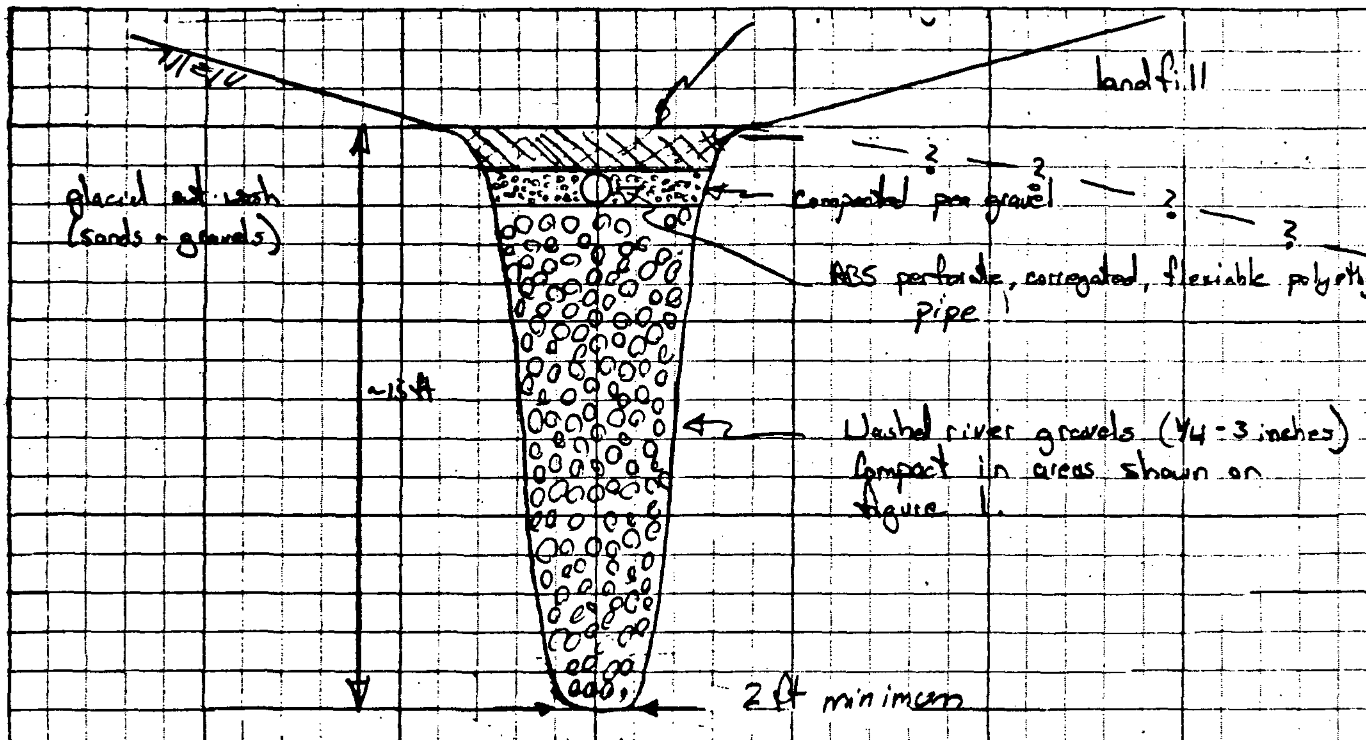
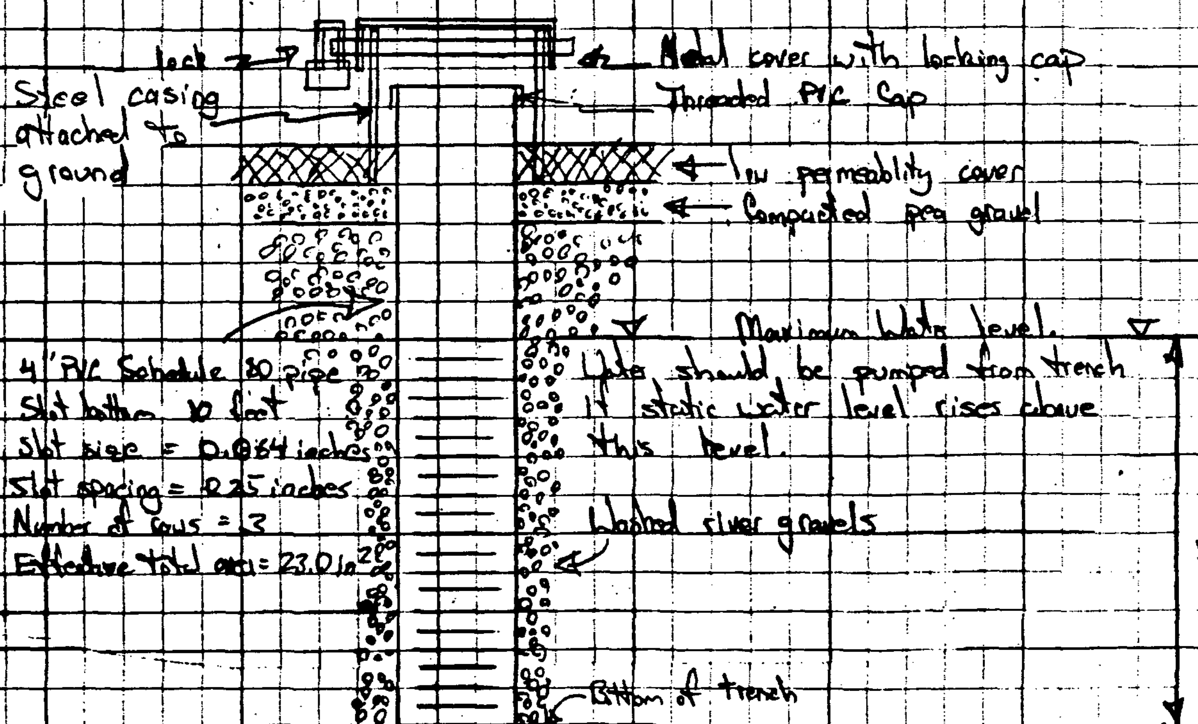
Figure 2

Golder Associates	SUBJECT Gas Collection Trench - Midway		
	Job No. 813-1276	Made by PGC	Date 2 Mar 82
	Ref.	Checked	Sheet 1 of 1
		Reviewed	



Typical Cross-Section of Gas Collection Trench
Scale: 1" = 5'



Details of Sump Well
Not to Scale

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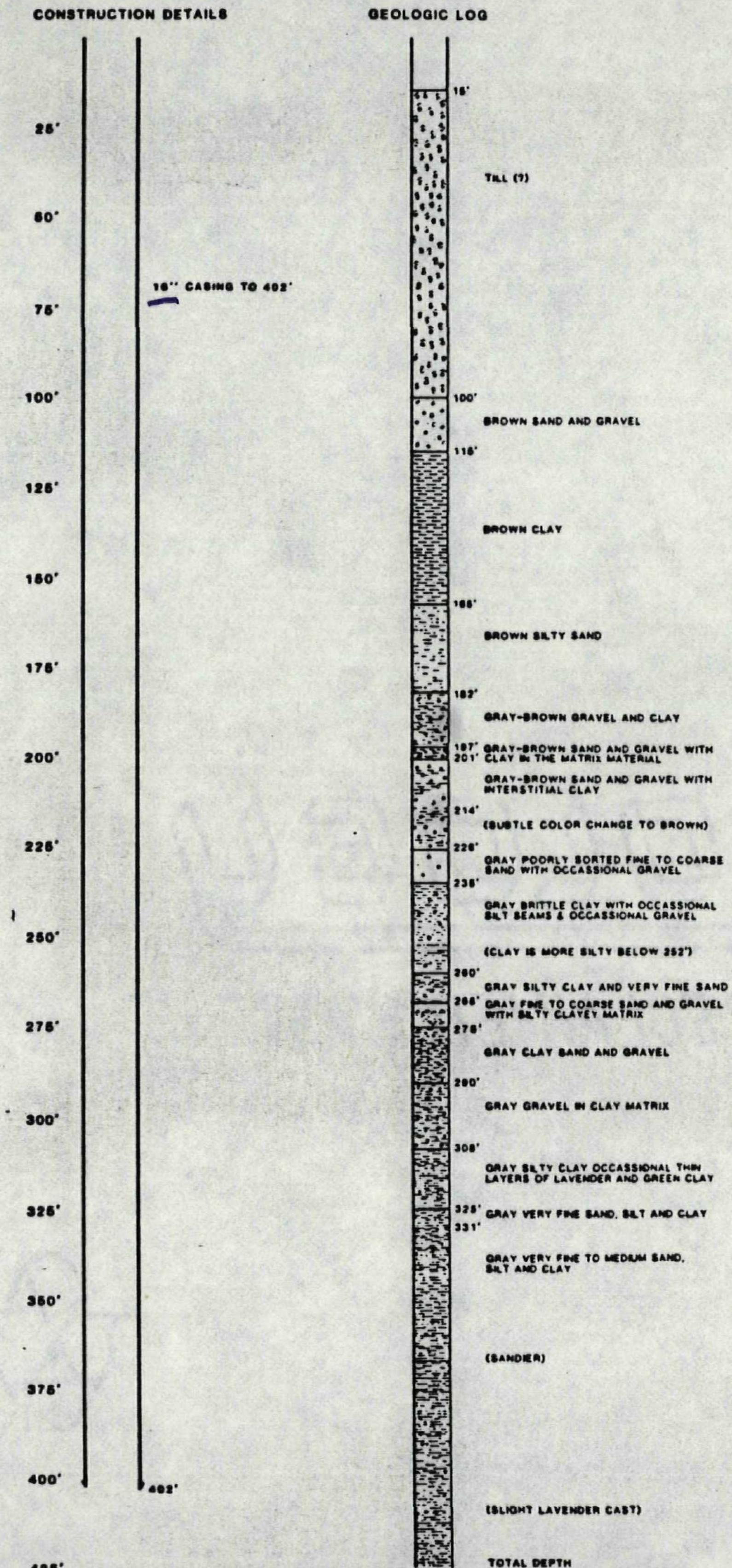
LINDA HEIGHTS WELL - DRILLER'S LOG

CITY OF KENT
Linda Heights, Well B

JOB# 79-71B



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ROBINSON & NOBLE, INC

From City of Kent

Golder Associates

Rev.
Dwg. No. 812-1276-142 Date June 82 Eng. P.C.

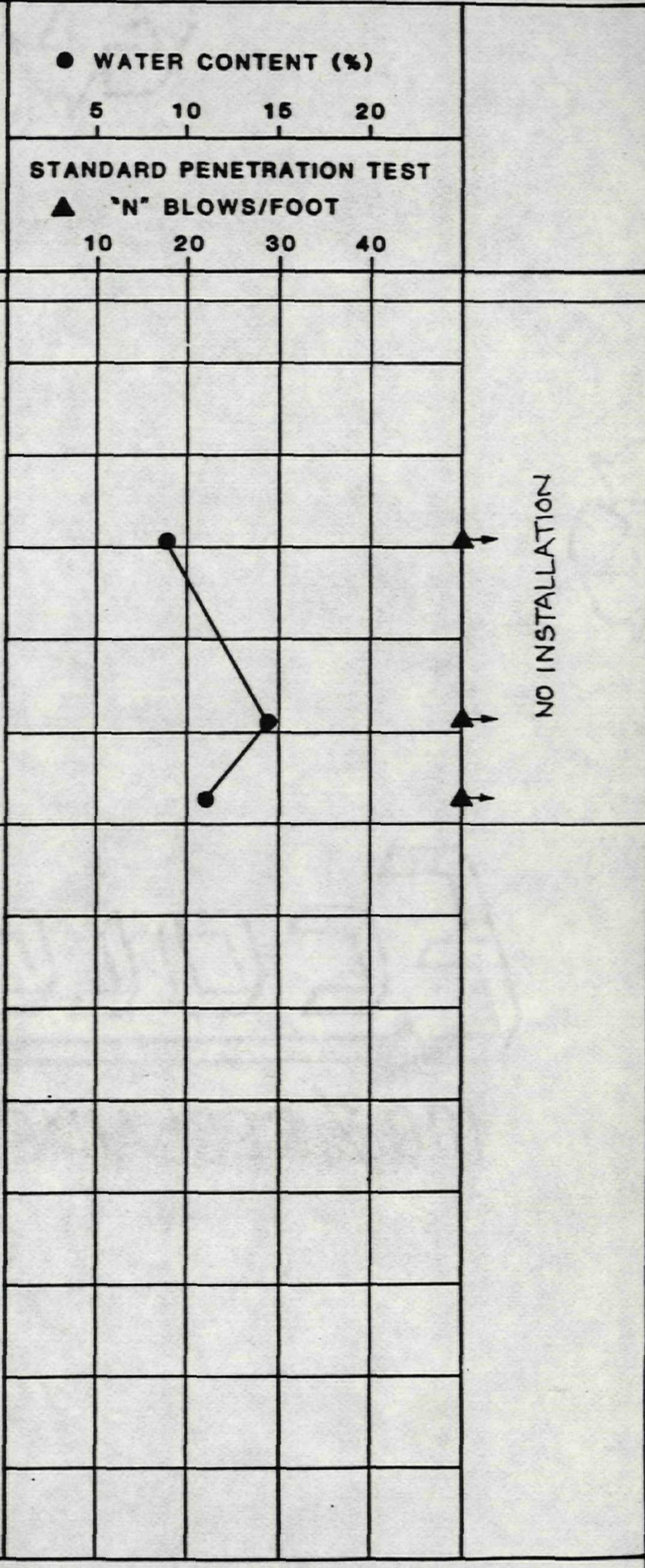
RECORD OF BOREHOLE BH-1A

COORDINATES: N 11,548 E 9,156 (approx.)

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 15 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 3⅜ in. I.D. hollow stem auger

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT. PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/FT.	ELEVATION
333.5 / 0						
331.5 / 2.0	Dense, brown and gray, coarse to fine SAND, some gravel					
	Very dense, brown and gray, coarse to fine SAND, some gravel, trace cobbles					330
323.5 / 10.0						325
321.5 / 12.0	Very dense, gray and brown GRAVEL and coarse to fine SAND					
			S-1	2" D.O.	80/3"	320
	Very dense, gray and brown SAND and GRAVEL, trace clay, silt and cobbles to silty SAND and GRAVEL					315
			S-2	2" D.O.	50/5"	310
305.0			S-3	2" D.O.	50/3"	305
28.5	End of Hole					



REMARKS: Hole terminated at 28.5 ft. due to refusal. No water in hole. Unable to take sample at 18.0 ft. due to boulder/cobble in hole. For water contents and standard penetration test results between 0 and 10 feet see BH-1.

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1

Dwg. No. A813-1276-011 Date Mar 82 Eng. P.C.

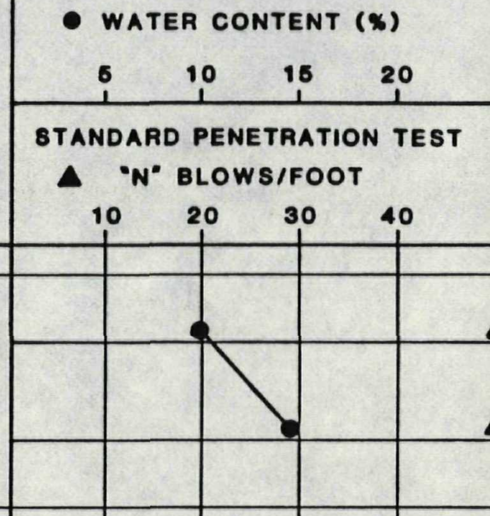
RECORD OF BOREHOLE BH-1

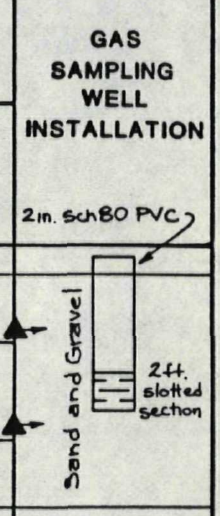
COORDINATES: N11,551.24 E9,147.62

LOCATION: Midway Landfill **DATUM:** MSL **DATE:** 15 January 1982

SAMPLER HAMMER WEIGHT 140 LBS., DROP 30 IN. **BORING METHOD:** 3⅜ in. hollow stem auger

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.	ELEVATION
333.5 / 0					
331.5 / 2.0	Dense, brown and gray, coarse to fine SAND, some gravel				
	Very dense, brown and gray, coarse to fine SAND, some gravel, trace cobbles	S-1	2.0" D.O.	75/9"	330
		S-2	2.0" D.O.	50/4"	325
321.5 / 12.0	End of Hole				





REMARKS: Hole terminated at 12.0 ft. due to auger refusal. No water in hole.
D.O. = 2in. Drive Open Sample

VERTICAL SCALE: 1 in. to 10 ft.

Golder Associates **DRAFT** Sheet 1 of 1